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NAVY COMMAND CONTROL AND COMMUNICATIONS SYSTEM: LAYERED ANALYTICS--ETC(U)  
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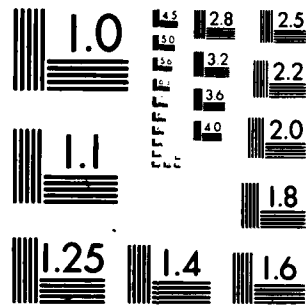
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## NAVY COMMAND CONTROL AND COMMUNICATIONS SYSTEM: LAYERED ANALYTIC MODEL

R.L. Goodbody

27 September 1981

Prepared for  
Naval Electronic Systems Command  
(Code 623)

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Technical Director

ADMINISTRATIVE INFORMATION

The work reported here was performed under element 65866N, project CG67811A01, under sponsorship of the Naval Electronic Systems Command (Code 623).

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NOSC Technical Document 479 (TD 479)	2. GOVT ACCESSION NO. AD-A112 245	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) NAVY COMMAND CONTROL AND COMMUNICATIONS SYSTEM: LAYERED ANALYTIC MODEL		5. TYPE OF REPORT & PERIOD COVERED Final October 1980-September 1981
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) R. L. Goodbody		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Ocean Systems Center San Diego, CA 92152		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 65866N, CG 67811A01
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Electronic Systems Command (Code 623) Washington, DC 20360		12. REPORT DATE 27 September 1981
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		13. NUMBER OF PAGES 60
		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report)  Approved for public release; distribution unlimited		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Command JINTACCS Control Combined operations Communications Networking Interoperability		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) An in-depth description of a layered model for analysis, planning, and implementation guidance of Command and Control (C <sup>2</sup> ) systems is presented. The model provides a comprehensive, structured check list of the necessary functions performed at each echelon in a command hierarchy. It is also a tool for checking that all interoperability requirements can be defined and compared against limiting conditions imposed by system design and integration, and is useful for developing and checking interoperability criteria for both interservice (JINTACCS) and combined operations. The model is intended as a tool for all phases of the C <sup>2</sup> engineering process from managing the initial (cont'd)		

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concept formulation through interactive development and initial configuration control, as well as lifetime update, configuration control, and support of an integrated global Navy C<sup>2</sup> system. Its application extends to management of interoperability with non-navy C<sup>2</sup> systems.

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## 1.0 INTRODUCTION

### 1.1 OBJECTIVE

The objective of this document is to produce an in-depth description of a tool (a layered model) for analysis, planning, and implementation guidance of Command, Control, and Communications (C<sup>3</sup>) systems. Hereafter, we will use the term Command and Control in lieu of C<sup>3</sup>. C<sup>2</sup> is considered to include communications. The tool is an extension of the International Standards Organization (ISO) Open Systems Interconnection (OSI) model which consists of seven layers.<sup>[1]</sup> This tool provides a comprehensive, structured check list of the necessary functions performed at each echelon in a command hierarchy. It is also a tool to check that all of the interoperability requirements can be defined and compared against limiting conditions imposed by system design and integration. It is useful for developing and checking interoperability criteria for both interservice (JINTACCS) and for combined operations. Throughout, the model will be referenced to the relevant JCS and Navy publications. The model is intended as a tool for all phases of the C<sup>2</sup> system engineering process from managing the initial configuration control, through iterative development and initial configuration control, as well as lifetime update, configuration control, and support of an integrated global Navy C<sup>2</sup> system. Its application extends to management of interoperability with non-Navy C<sup>2</sup> systems.

### 1.2 BACKGROUND

Analytical methods have been improved in recent years to develop block diagram models of the C<sup>2</sup> system and functions. These efforts have met with some success but major improvements are needed and possible. A new methodology for layered system representation (the OSI reference model) is now under development by the American National Standards Institute and the International

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1. Zimmermann, H., OSI Reference Model - The ISO Model of Architecture for Open Systems Interconnection, IEEE Transactions on Communications, vol Com-28 no 4, p 425-432, April 1980.



Standards Organization and has gained the support of the IEEE. A description is given by Zimmermann.<sup>[1]</sup> The method provides a basis for a scientific approach to the representation of very large (global in scope) and complex systems such as for Navy C<sup>2</sup>. To date, the model has developed primarily from the point of view of the communications and computer scientist and engineer. This document extends the OSI model to include the operational and command point of view as well as to address military requirements for survivability, security, tactical mobility, and tactical information exchange.\*

To date (because an analytical model such as OSI has been lacking), description and analysis of the Navy C<sup>2</sup> system have been in mostly narrative form, poorly structured, and lacking in coherence and semantic consistency. We have not had the adequate system science tools to do much better than that. The OSI model, which has the broad support of the US and international scientific and industrial communities, provides a basis for such a tool. A tool based on the OSI model should guarantee that its use by the Navy will lead to systems which will be affordable and well supported by the US industrial base in the future.

### 1.3 SCOPE

This document lays out the generic layered analytic model as it applies to a unified Navy C<sup>2</sup> system for creating surveillance, intelligence, communications, decision, command support, and counter-C<sup>2</sup> products.<sup>[2]</sup> An important

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\* For example, air combat requires tactical information exchange by means of voice messages with expected durations of approximately 0.6 second (as short as 0.1 second, eg; a key click), and tactical data messages of approximately 100 bits. These messages are very perishable with allowed input-to-output delays of 0.1 to 10 seconds (eg, 1 second for each track update on a mach 4 missile). Peak aggregate volume in a network from multiple sources could be on the order of 400 messages per second.

2. NOSC TD 347, Navy Telecommunications System (NTS) 2001, R.L. Goodbody, vol 1, p 6-7, June 1980.



and possibly controversial point of view is taken in this document that any person in the Navy is considered to be a node at some echelon in the Navy command hierarchy, and that the operation of these persons can be prescribed in terms of the model. Thus the Fleet, CINC, OTC, CO, TAO, Operations Officer, Air Intercept Controller, Supply Officer, and members of the engine room crew are all examples of such nodes at various echelons in the command hierarchy. All of these interoperate in some way constrained by conditions of their own capabilities, by the capabilities of the information network tying them together, and by constraints imposed by superiors and environment. The layered model is a technique for expressing all of these conditions in a standard format. This document, by developing the generic structure, lights the way to further useful work.

The document is useful to many types of readers. The seven-layered model was designed to express many points of view (at least seven) and allows these points of view to develop in detail without a need to understand the whole system. Thus, for example, a reader interested in operational applications can concentrate on the application layer and need not know nor be concerned about how the telecommunications links function. Technologists call this "system transparency" and/or "information hiding".

#### 1.4 OUTLINE OF THE DOCUMENT

The heart of the document is in the appendix, which describes the generic layered model. Sections 2 and 3 provide the introduction to, and summary of, the material in the appendix. Section 4 is an illustration of multilayer internetting in a local network or networks.



## 2.0 INTRODUCTION TO LAYERING

Society, both military and civilian, is becoming ever more dependent on efficient, effective global distribution of information. (One group of authors has predicted that by the year 2000 more than one-half of the US Gross National Product would consist of the generation, handling, and consumption of information.<sup>[3]</sup>) There is a growing international need for interface standards - in effect, an international "constitution" - which will provide a mechanism for independent people, organizations, and nations to interoperate while protecting their own autonomy and diversity in development and use of information systems.

The ability of people (and machines) to communicate (and exchange data) depends on compatibility and cooperation at many layers. At the highest layer is the agreement on an operational concept (whether in a game such as basketball or in military operations), which is the basis for teamwork. At the next lower layer, an agreed-on language set is required (German, English, etc), along with a set of derived brevity codes or signs for speed, reduced ambiguity, and ease of translation from one language to another [eg, the maritime signal book ATP-1(B)]. At lower layers, network control, access and scheduling, data organizing and message standards, voltage levels, wire connections, etc, all must be agreed to.

If compatibility is achieved at all layers in a system, interoperability is said to be achieved. The agreements on all these procedures and standards are called protocols. When a set of protocols at each layer of the system exists, we have what is called a multilayer protocol.

Some of the layering principles considered by the ISO for the layered model are as follows:<sup>[2]</sup>

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3. Kahn, Robert E., Keith Uncapher, and Harry L. Van Trees, Scanning the Issue - Special Issue on Packet Communication Networks, Proceedings of the IEEE, vol 66, no 11, p 1303, November 1978.



1. Create enough layers for sufficient detail but not so many as to overly complicate describing and integrating the layers (a human factors limitation and thus the seven layers).
2. Create boundaries where service descriptions are small and interactions across the boundary are minimized.
3. Create separate layers for functions which are manifestly different.
4. Collect similar functions into the same layer.
5. Select boundaries on the basis of past successful experience.
6. Make the functions easily localized within layers so that changes resulting from new developments or requirements can be introduced without major effect on adjacent layers.
7. Create a layer where the need for a different abstraction exists. (For example, the Fleet Operational and the engineering communities understand the system in terms of different abstractions. Therefore, different layers are required to express these different points of view. On the other hand, an integrated system concept requires dialog between these two communities. Thus a layered model must provide for such interaction and interfacing).
8. Connect a given layer only to the layer immediately above or below.
9. Create sublayers for further subdivisions for functions.
10. Allow bypassing of sublayers. However, this statement will be interpreted for our purposes to mean that any data which pass a sublayer without change can be diagrammed as passing through the sublayer via a short circuit. Therefore, no connections will be shown bypassing a sublayer. This short-circuit convention allows diagrammatic consistency and simplifies initial design.



The OSI model currently considers system management functions to be applications of a special type<sup>[1]</sup> and therefore allows violation of the layering principles for these functions. We do not make any such exception and insist on applying the layering principle to all functions and data. The rationale for this is that the layering principle allows different points of view to be expressed and compatibly interfaced within the same system. A management message from the point of view of the Fleet CINC and CO (eg, establishing the EW plan for a future operation) is just data to be transported from the point of view of the telecommunication link operation. And conversely, the Fleet CINC is not interested in, nor knowledgeable about, generating all the signals directly establishing telecommunication equipment operating modes. He merely issues a plan which is translated and implemented as required by successive layers and echelons. Thus the layered architecture applying to all functions including management is also an expression of the military principle of delegation of authority and tasks.

An illustration of layering is as follows.

Admiral Brass tells his secretary to connect him with Admiral Scrambled Eggs. He doesn't need to know the telephone number - the secretary does. Nor does the secretary need to know what one admiral is going to say to the other. The secretary dials - he or she doesn't know where the dial signals go nor how the connections are made and the secretary at the other end answers. The secretaries exchange a few coordination remarks, the two admirals are connected, and the secretaries get off the line. The admiral instructs his secretary; the secretary translates this instruction into a number sequence and in turn to a dialed instruction to the telephone system, etc, through successive layers of management protocols and functions. Admiral Brass did not need to know, nor have any direct access to, any layers (eg, telephone network switches and link layers) in the system other than his secretary. But he has efficiently and effectively used the resources available to manage a connection to the other admiral.

Another illustration of layering is the analogy to the onion shown in figure 2-1. The seven layers of the OSI model are labeled, and illustrative



sublayers are shown. A path from one layer to any other proceeds only via the intervening layers and sublayers.

A note of caution is in order at this point. The model documented here is a logical construct. It does not necessarily represent a proposed physical existence but is intended to show logical relationships. How these logical relationships map into a real physical construct is still to be determined. But the layered model is a major step in the direction of prescribing how a C<sup>2</sup> system should work so that a better understanding of how it is to be built is possible.

The layered model is proposed as the basis for structured MIL STDS as well as Type A functional and interface specifications for a unified Navy C<sup>2</sup> system and its subsystems. The model is a basis for unifying the statements of operational requirements and the supporting functional specifications in a single document. The layered format, because it documents supported and supporting functional relationships, is what allows unified treatment of requirements and derived functional specifications in supporting layers.



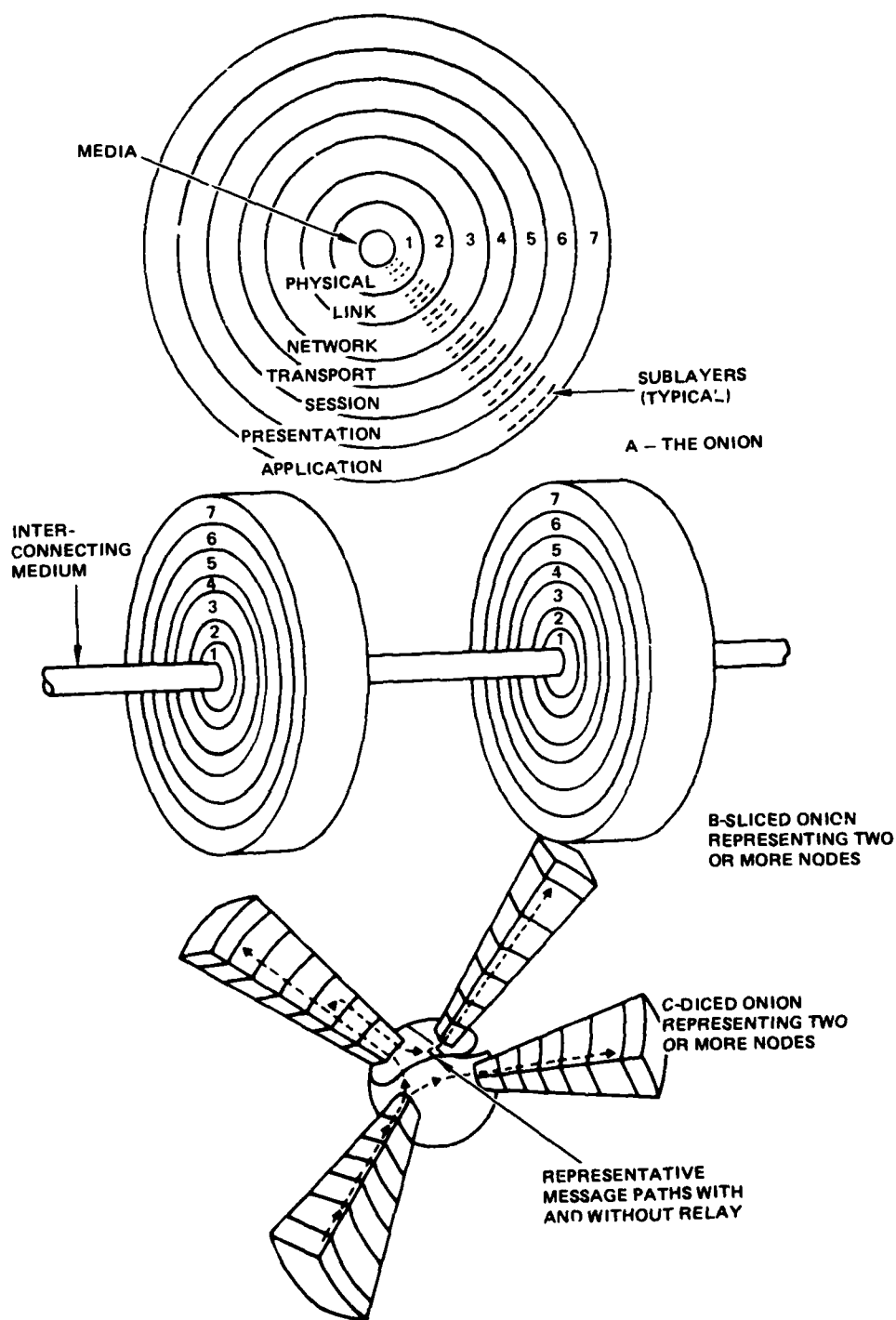


Figure 2-1. The onion as an analog of layered protocols.



### 3.0 SUMMARY OF THE LAYERED ANALYTICAL MODEL OF NAVY C<sup>2</sup>

To do a 'top-down' design, the system engineer would like to start by describing the operational uses of the system (application layer) and then iterating step by step (layer by layer) to specify the supporting functions of the system. That is the order of the list of layers as shown below.

The seven layers of the OSI model are summarized as follows:

Application of network data and system management to military operations. Includes node management with access via intervening layers to all lower layers.

Presentation. Provides format transformations of information being transferred for user and host interactions.

Session. Provides sessions or high-level connections supporting dialog and conferences among end users or host computers.

Transport end-to-end control. Provides transport of messages across an arbitrary topological configuration through several interconnected networks.

Network. Provides multiple channels for transferring information among nodes in a communication network.

Link. Provides for exchange of data and signals across a single data link.

Physical. Concerns the means of transmission across a physical medium.

Figure 3-1 summarizes the Navy C<sup>2</sup> layered system analysis given in the appendix. The summary diagram includes the decimal numbering system of the appendix and brief titles of the layers and sublayers.



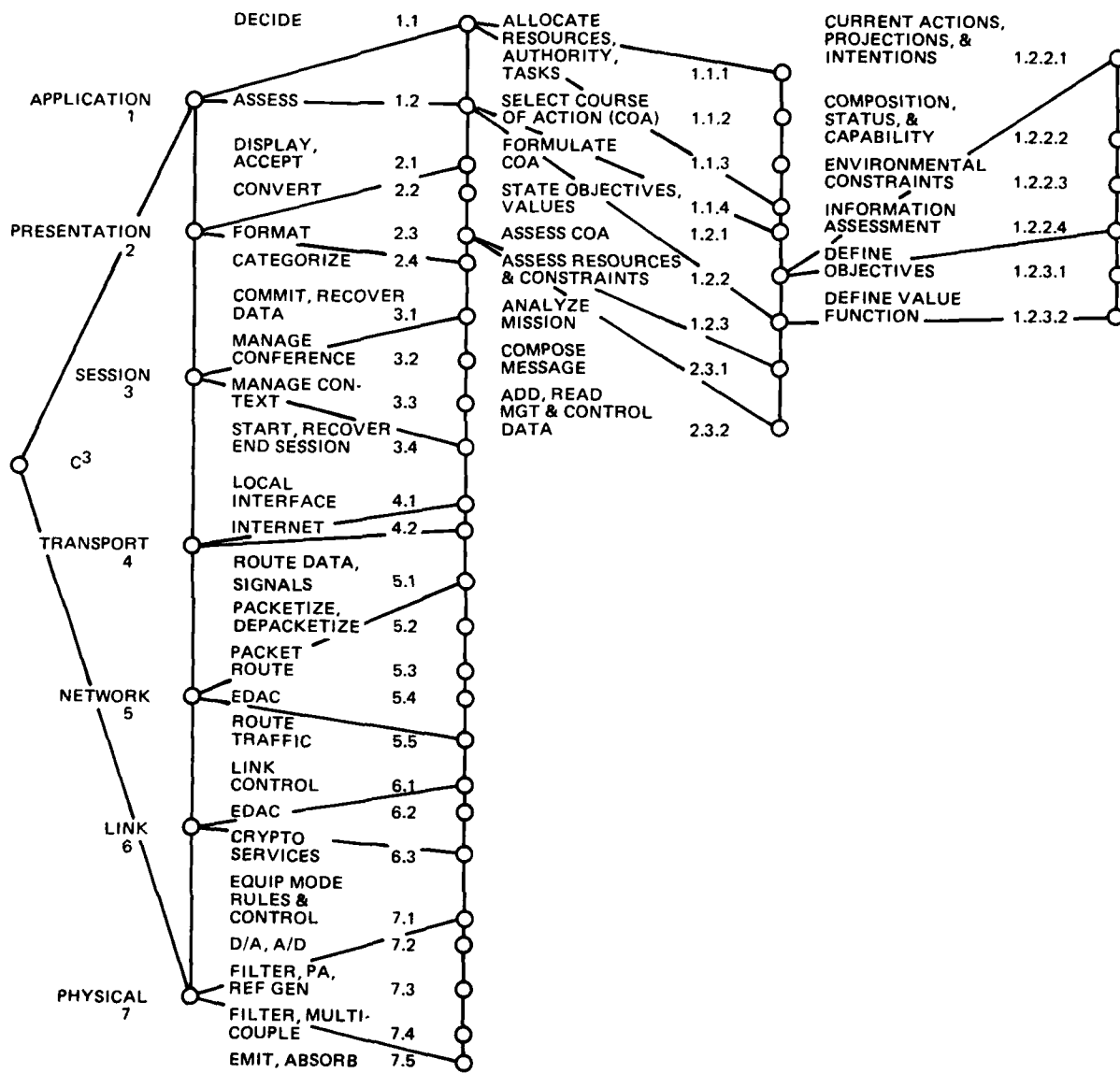


Figure 3-1. C<sup>3</sup> system layered breakdown structure.



Additional detail of system analysis may be desired and is left for further research. It should be noted that the layering method is used for practical reasons in the analysis of large, complex systems. At some level of analytical detail, or for small well understood systems, the rules of layering may not serve a useful purpose. In such cases, it may be desirable to use the traditional nonlayered functional, state, logic, and hardware wiring diagrams.

A documentation convention used here is that only two pages - one diagram and one page of text - are allowed for defining and describing any given layer or sublayer at a given level of detail. If more detail is required, more pages are added for additional (sub) sublayers [two pages per additional (sub) sublayer] in accordance with the structure shown in figure 3-1. Thus each decimal-numbered and titled layer or sublayer in figure 3-1 is associated with identically titled and numbered processes in the appendix. The diagrams are in standard form with all necessary boxes and connections given. The designer or analyst must only decide how many layers (one or more of the seven OSI layers) or sublayers (1 to 7) he wishes to have for description at a given level of detail, select the form with the appropriate number of boxes (from annex I of the appendix), and fill in the appropriate labels in the boxes on the form. No new boxes or connections are allowed. The whole analysis process is thus reduced to filling in labels and checking consistency. Figure 3-2 shows the basic building block. Figure 3-3 shows the form from the appendix, annex I, which strings five of these building blocks together for five sublayers.

The sequence of (sub)layers is such that a given (sub)layer always supports the (sub)layer to its upper left on the diagram (figure 3-3) and is supported by the (sub)layer to its lower right.\*<sup>4</sup> If these support relationships do not result from the analysis, then either the analysis is in error or a layered analysis is not appropriate for that level of detail. In many cases, since the layered processes are reiterative, the choice of ordering the sublayers may seem like a "chicken-and-egg, which came first?" dilemma. In such a case, a judgement must be made and one way chosen.

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\* This is just the opposite of traditional diagrams which show processes in a time sequence (from left to right), as in figure 1-1 of NWP-11 (ref 4).

<sup>4</sup> CNO, NWP-11 (Rev C), Naval Operational Planning, December 1978.



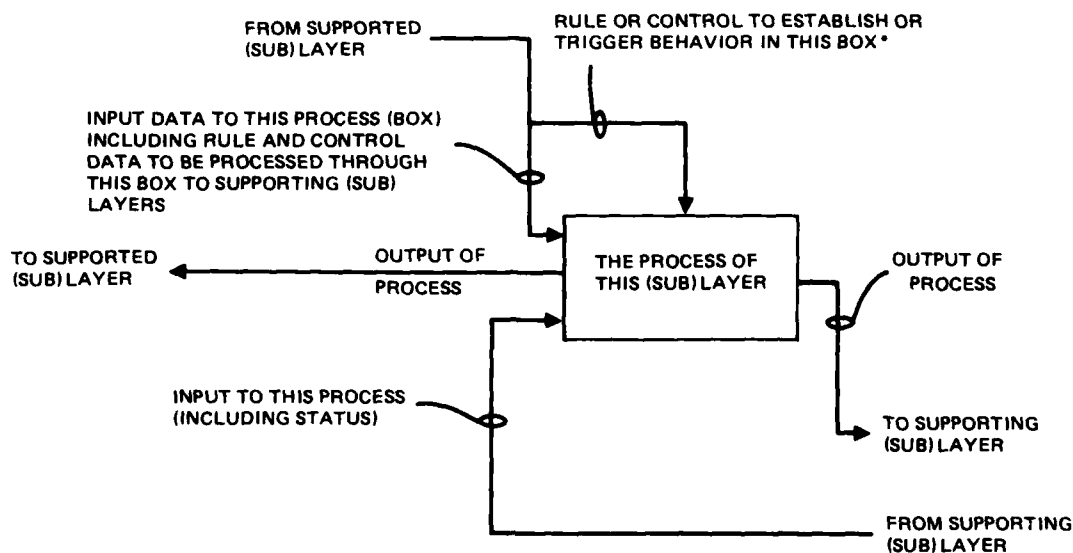


Figure 3-2. The basic building block.

Notes to Figure 3-2:

1. A process entity at layer N can communicate directly with other process entities only at supporting or supported layers. (But at some level of detail, layering ceases.) This rule extends to sublayers as well; ie, no connection line can skip any intervening layer or sublayer. Peer entities communicate only via a common entity in a supporting (sub)layer.
2. Rule or control data\* applied at a (sub)layer always originate at supported (sub)layers.
3. Rules or controls are special kinds of input. They appear at the control/rule input arrow only on those boxes where applied as rule or control. Otherwise, they stay on input or output arrows.\*\*
4. No queues are shown on a layered diagram. They are shown only at a level of detail where layering is not imposed.

\* Rules establish the potential behavior of process entities. This potential behavior is activated when triggered by one or more associated controls.

\*\* Determining whether rules or controls are shown on input or output arrows must be based on iterative analysis down to the lowest detail. Until this lowest level of analysis is reached, the location of control labels in the diagrams must be considered provisional.



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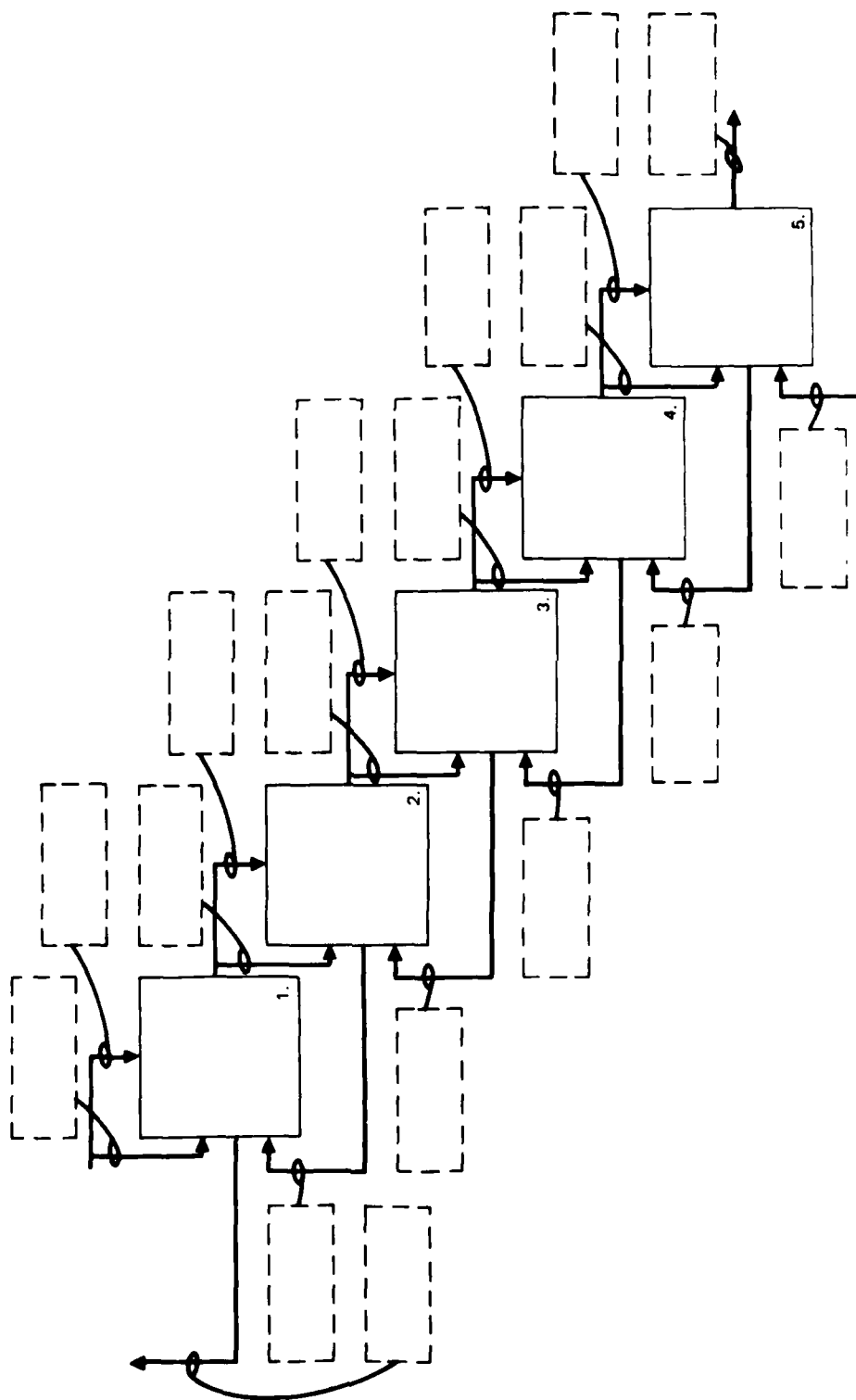


Figure 3-3. Example of form for layered analysis.



The labeling used in the layered diagrams must be very abbreviated because of the limited space available. The list of these abbreviations is given in annex II of the appendix.

The OSI model is intended to represent modern digital switched networks. In applying this model to Navy C<sup>2</sup>, the definitions and descriptions are in terms which allow representation of existing (including manual) and transitional systems by the model. Thus, for example, analog signals (represented by the label S) could be propagated through all layers up to and including presentation. In such a case, processes of many (sub)layers would be represented by a short circuit. (For example, in paragraph 5.2, Packetize and Depacketize Sublayer functions would not be carried out on S. S is therefore short-circuited through this sublayer.)



#### 4.0 A NETWORKING EXAMPLE

Figure 4-1 shows an example of a network concept for a platform (eg, a ship). Users and user centers within the platform are shown netted together and connected to the outside world via exterior radio communications, sensor, and EW systems. The various localized user networks are cryptographically protected (red) and are tied together via shipwide media (eg, a data bus) which may not be cryptographically protected (black). But the shipwide media are protected to the extent of ensuring integrity of network control and management.

The networks are interfaced by functions associated with one or more of the OSI layers. Where the user center networks are highly homogeneous, the internetting (eg, between the admin center and other user center nets in figure 4-1) may be very simple, requiring at most only Physical and Link layer functions. In cases where networks are more heterogeneous (because of unique user requirements or evolving technology), more complex internetting may be required - necessitating Network, Transport, Session, and even Presentation Layer functions. These possibilities are illustrated in figure 4-1.

Issues concerning which functions are required for internetting are still to be resolved by further research for specific cases. Such an issue is the provision of crypto service for user data as well as to ensure network integrity (COMSEC) in a multilevel and compartmentalized security environment. Another issue is the relay function: if the node is intended to provide relay service in a network, how sophisticated and at what cost is this to be done? For example, the least sophisticated relay could be just a reflecting balloon (physical layer only). A slightly smarter relay could be an  $f_1$  to  $f_2$  relay; or link layer functions may be added such as forward EDAC; or network layer functions such as adaptive routing over multiple links may be desired. The more layers involved in providing a capability, the more effective but also the more costly in hardware/software, processing time, and dollars.

Layering is a system management tool for making such cost/effectiveness tradeoffs and comparisons clearer, simpler, more explicit, and more understandable.



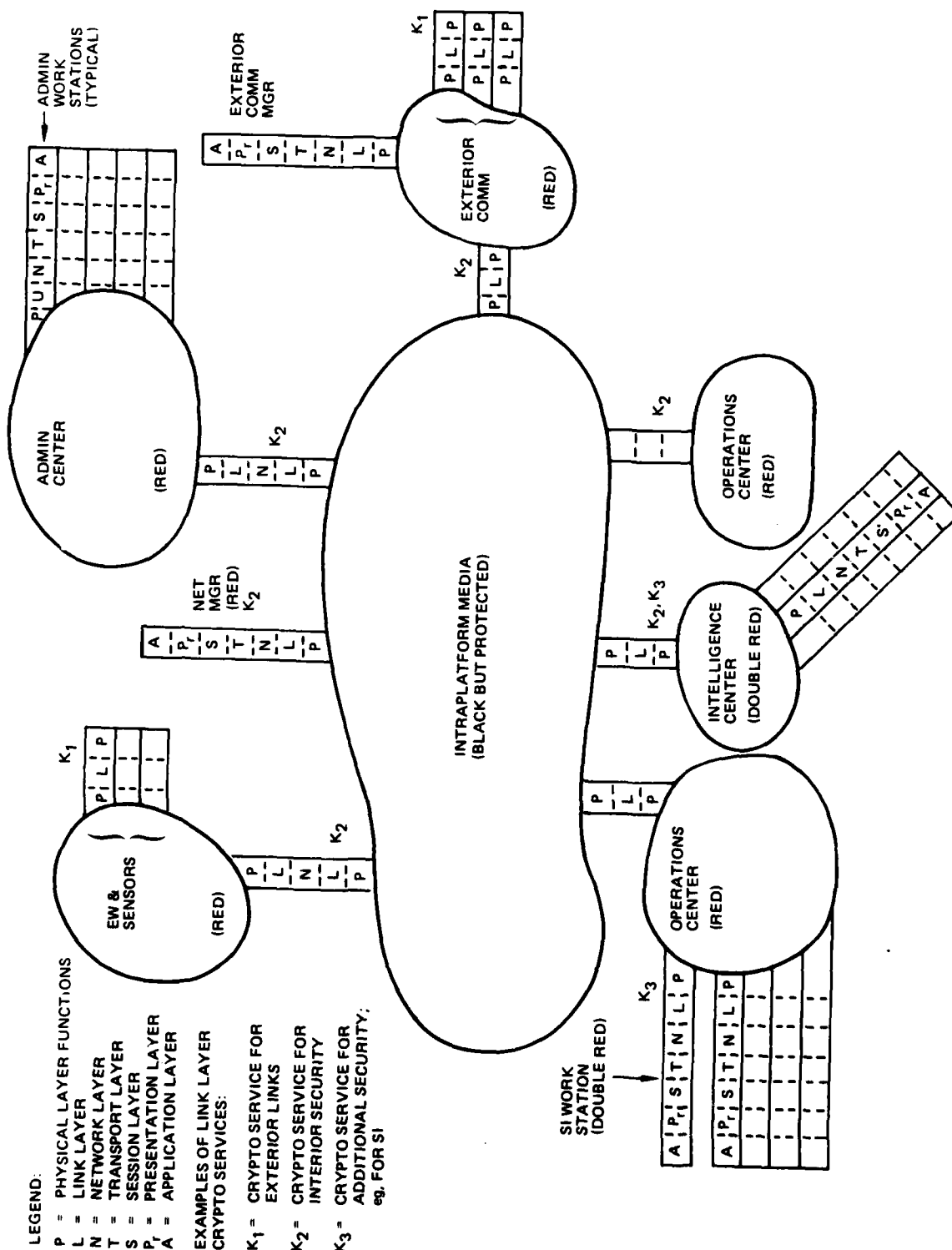


Figure 4-1. Example of networking concept.



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1. Zimmermann, H., OSI Reference Model - The ISO Model of Architecture for Open Systems Interconnection, IEEE Transactions on Communications, vol Com-28, no 4, p 425-432, April 1980.
2. NOSC TD 347, Navy Telecommunications System (NTS) 2001, R.L. Goodbody, vol 1, p 6-7, June 1980.
3. Kahn, Robert E., Keith Uncapher, and Harry L. Van Trees, Scanning the Issue - Special Issue on Packet Communication Networks, Proceedings of the IEEE, vol 66, no 11, p 1303, November 1978.
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**APPENDIX**  
**GENERIC LAYERED MODEL OF NAVY C<sup>2</sup>**



## NAVY C<sup>2</sup>

**Definition:** Command and Control is defined as "The exercise of authority and direction by a properly designated commander over assigned forces in the accomplishment of his mission. Command and control functions are performed through an arrangement of personnel, equipment, communications facilities, and procedures which are employed by a commander in planning, directing, coordinating and controlling forces and operations in the accomplishment of his mission" (JCS pub 1). A C<sup>2</sup> system generates the following five products: Surveillance and Support Product (SP), Intelligence and Assessment Product (IAP), Communications Product (CP), Decision Product (DP), and Counter-C<sup>2</sup> Product (C-C<sup>2</sup>P).<sup>\*</sup> A Command and Control system is "The facilities, equipment, communications, procedures, and personnel essential to a commander for planning, directing and controlling operations of assigned forces pursuant to the missions assigned"<sup>\*\*</sup> (JCS pub 1).

**Description:** In conformity to the OSI model, the Navy C<sup>3</sup> system is an echeloned network of nodes in which each node is functionally described in terms of seven layers.<sup>\*\*</sup>

1. Application, in which reside the end-user information services and application processes for performing end-user tasks of assessment and decision making.
2. Presentation, in which entry and display of data are controlled so that the data are meaningful to Application Layer processes.
3. Session, which assists in the support of interactions and conferences between cooperating Presentation Layer entities and provides session and conference administration service.
4. Transport, which provides internetwork interfacing and interfaces the Session Layer with data transport networks.
5. Network, which binds multiple links and nodes together for data transport. Provides multimedia traffic routing, relaying, and control.
6. Data Link, which arranges and conditions data, and provides procedures for data transport via link resources which connect nodes. It provides/receives signals, data and error-encoded encrypted data to/from the Physical Layer, and provides/receives data streams and packetized data to/from the Network Layer.
7. Physical, which provides the physical signal path to/from the electromagnetic, acoustic, and mechanical media external to the node, and accepts/delivers signals, data, and encrypted digital data from/to the Link Layer.

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<sup>\*</sup> Counter-C<sup>2</sup> products are not shown in the generic diagrams and discussion of this appendix.

<sup>\*\*</sup> There are also C<sup>2</sup> components which perform only internetting and relay and therefore may omit one or more layers.







## 1 APPLICATION

**Definition:** The Application Layer contains the user services functions which receive, via the Presentation Layer, the following products: Locally generated Surveillance Products (SP), SP' (the prime is a symbol denoting a product generated at another node); Communications, Intelligence/Assessment, and Decision Products generated at other nodes (CP, IAP', DP'). SP or SP' (both data and signals) may include administrative, personnel, logistic, and similar Support Products as well as statements of services or duties performed, characteristics, position, time, identity, organizational data, and similar information on historical events and cause-effect relationships. IAP may include assessments of value, significance, degree, meaning, quality, condition of the data, or signals in the SP as well as relevant conclusions. CP may include statements of understandings, assumptions, hypotheses, concepts, and philosophy which are exchanged and mutually understood among two or more persons. The Application Layer generates and delivers to the Presentation Layer IAP, CP, and DP. DP may include statements of policy, mission, strategy, plans, doctrine, recommendations, task assignments, resource allocations, delegation of authority, intentions, tactics, rules, procedures, instructions, orders, control, directives, requests, limits, constraints, and thresholds. The DP may include the outline plan, campaign plan, operations plans and orders, logistic plan, base plan, communication plan, intelligence plan, and psychological warfare plan as defined and described in NWP-11. Typical formats (Joint Operations Planning System, Unified Action Armed Forces, JCS Pub 2) are provided in NWP-11 for information. (NWP-11 chapter 3 describes development of an operational plan and directive and chapter 4 describes the directive format. Other chapters describe development and format of other plans.)

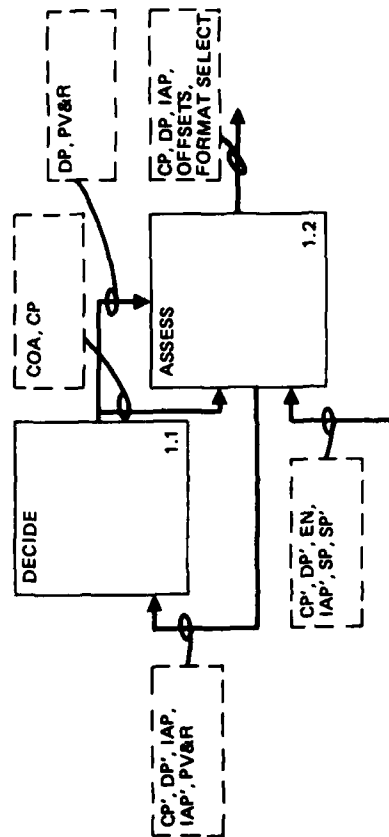
**Description:** The Application Layer consists of two sublayers:

1. Decide, in which decisions are made and DP generated based on IAP, IAP', CP', DP', and Payoffs, Values, and Risks (PV&R) received from the Assessment Sublayer.
2. Assessment, which generates IAP and processes IAP', CP', DP', and PV&R for delivery to the Decide Sublayer. This is based on CP and Course of Action (COA) inputs as well as rules and controls imposed by DP and PV&R from the Decide Sublayer. Assessment also delivers IAP, CP, and DP to the Presentation Layer based on the inputs and rules and controls from the Decide Sublayer. Any residual errors in the information which have been detected but not corrected will be notified to the Assessment Sublayer by the Presentation Layer by means of an Error Notification (EN).



No: 1

Title: Application





### 1.1 Decide

**Definition:** The Decide Sublayer generates the CP, DP, COA, and the decision makers' own PV&R based on IAP, IAP', CP', and PV&R inputs from the Assessment Sublayer. The Decide Sublayer has no connections other than to the Assessment Sublayer. "Decision" is defined in JCS Pub 1 as follows: "In an estimate of a situation, a clear and concise statement of the line of action intended to be followed by the commander as the one most favorable to the successful accomplishment of his mission".

**Description:** Decide consists of four sublayers:

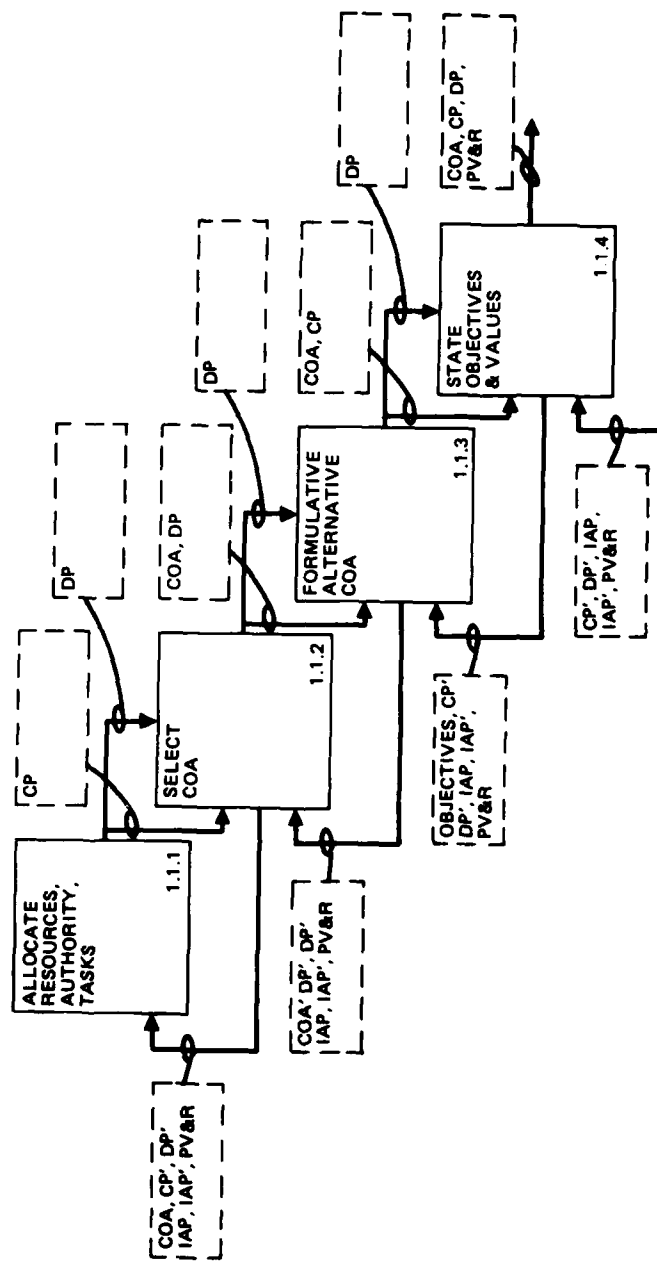
1. Allocate Resources, Authority, & Tasks, in which the decision maker generates and states his strategy, plans doctrine, operational concepts, rules, procedures, instructions, orders, controls, etc, with regard to resources (authority over, obtaining, allocating, and use of resources in space and time). This is all done on the basis of prior assessments of mission, resources, constraints, alternative courses of action, statements of objective, and choice of a COA. (See NWP-11 chapter 3 for description of this process as it relates to OP Plans for naval forces.)
2. Select COA(s), in which a progressive narrowing in on a COA is achieved based on interactions with Formulate COA, PV&R statements, and IAP. The statement of the COA includes a description of the expected enemy COA. When related to OP Plans for naval forces, this process is given in section 2.2.5 of NWP-11.
3. Formulate COA, in which own and enemy alternative COA are developed or postulated based on objectives, PV&R, and IAP as well as DP, CP'. COA is defined in JCS Pub 1 as: "Any sequence of acts which an individual or a unit may follow. A possible plan open to an individual or commander which would accomplish or is related to the accomplishment of his mission". The formulations are sufficiently complete to allow comparison and tradeoffs among alternatives. When related to OP Plans for naval forces, this process is covered as sections 2.2.3.2.1 and 2.2.3.2.4 of NWP-11.
4. State Objectives and Values, in which a progressive refinement of the decision maker's statement of objectives and values is achieved through iterative assessment and reassessment of PV&R, resources, constraints, and mission.

**Note:** The Counter-C<sup>2</sup> product is not shown in the generic model. Psychological Warfare (PSYWAR), as defined in JCS Pub 1 and described in NWP-11, is not included under C-C<sup>2</sup>.



No: 1.1

Title: Decide





## 1.2 Assess

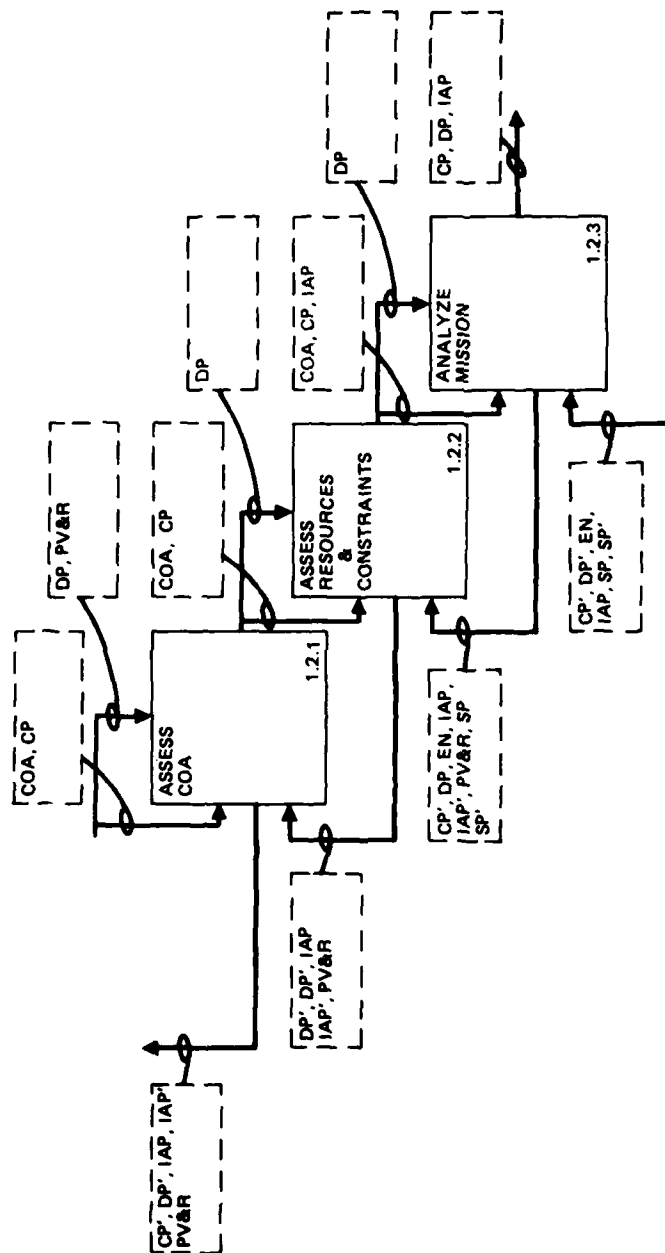
**Definition:** "Assess" means to analyze critically and judge definitively the nature, significance, status, or merit of; and to determine importance, size, or value of. This sublayer is where the IAP and part of the PV&R information is generated on the basis of CP, COA, SP, SP', IAP', CP' and DP' as constrained by DP and the decision-makers' own perceived PV&R. Continuing iteration and assessment of the decision makers' perceived PV&R is a major activity of the assessment sublayers. CP and DP from the Decide Sublayer are processed through to the Presentation Layer essentially unchanged. In particular cases (such as EW, Sigint, and ASW nodes), raw analog signals may be input for signal analysis and assessment.

**Description:** Assess consists of three sublayers.

1. Assess COAs, in which COAs which were formulated and selected in the Decide Sublayer are subjected to iterative analysis to determine PV&R. The relative merits of various COA are weighed, including the question: Is this the utmost that can be done in carrying out the assigned task or mission? Tests for suitability, feasibility, acceptability, affordability, and success\* are applied to each COA. This is based on iteration with Assess Resources and Constraints (R&C) and Analyze Mission. When related to OP Plans for Naval Forces, this process is given as steps 3 and 4 of "Estimate of the Situation" in NWP-11 except that NWP-11 sections 2.2.3.2.1 and 2.2.3.2.4 are in the Decide Sublayer.
2. Assess Resources and Constraints (R&C), in which own and other actions, force composition and status, information, and the environment are all analyzed. This analysis activity is based on and iterated with mission analysis information. NWP-11 appendix D provides a 31-page check-off list for Intelligence. Assessment of the environment is given as step 2 of "Estimate of the Situation" in NWP-11.
3. Analyze Mission, in which objectives are iteratively defined so as to support and focus assessments of resources, constraints, and COA, and to ultimately support the decision process itself. Mission analysis is given as step 1 of "Estimate of the Situation" in NWP-11.



No: 1.2 Title: Assess





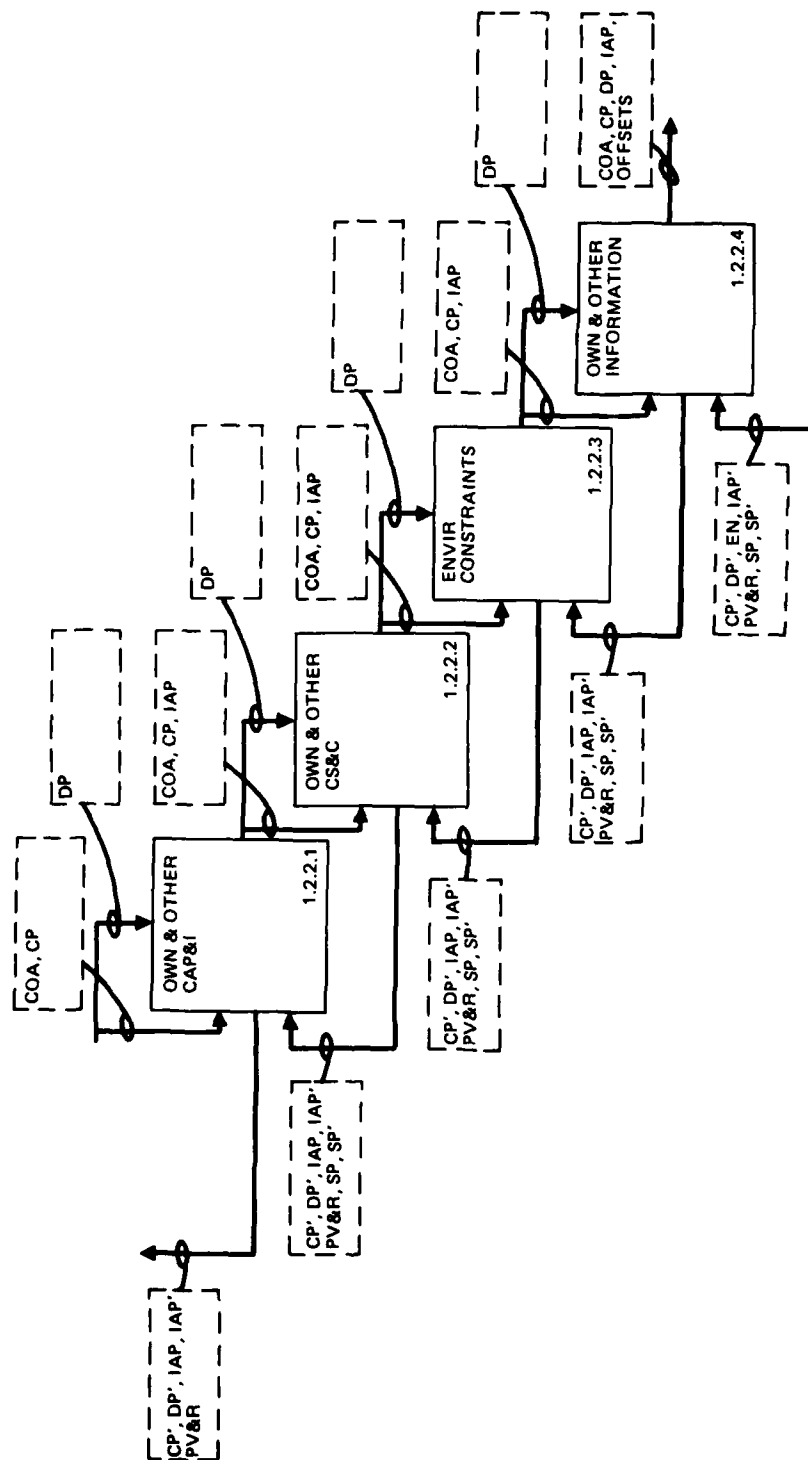
### 1.2.2 Assess Resources and Constraints (R&C)

**Definition:** Resources and constraints are assessed as directed or tasked by the DP, and in the context of a chosen set of COA and communications among participants in the assessment and decision-making process. This requires SP, Sp', IAP', and PV&R inputs.

**Description:** Assess Resources and Constraints consists of four sublayers:

1. Own and Other Current Actions, Projections, and Intentions (CAP&I), in which assessments are made of own and other alternative COA. This includes assessment and discovery of stratagem, deception, and similar counter-C<sup>3</sup> actions and intentions as well as the prediction of behavior as a function of space, time, and inputs.
2. Own and Other Composition, Status, and Capability (CS&C), in which assessments are made of deployment patterns, trends in consumption, inferences about capability from composition and status (eg, radar detection circles, combat radius), camouflage, and deceptive deployments. CS&C may include susceptibilities, vulnerabilities, exposure, OB, EOB, detection and combat ranges, and characteristics assessments which are functions of space, time, and frequency.
3. Environment Constraints (EC), in which assessments are made of environmental factors which may constrain freedom of action of both own and other decision makers and forces. EC may include weather, climatic, geographic, topographic, oceanographic, hydrographic, electromagnetic, acoustic, radiological, chemical, biological, physiological, psychological, economic, sociological, political, legal, and cultural assessments.
4. Own and Other Information Assessment (IA), in which assessments are made of the information itself which is available to own and other decision makers. This may include assessment of: (a) the effects of stratagem and deception, (b) correlation and analysis of data and/or signals from multiple sources (eg, radar, sonar, ESM, OSIS), (c) information available to others who may monitor our C<sup>3</sup> activities and signals, (d) OPSEC effectiveness, and (e) possible counteractions resulting from transport and manipulation of multiple information entities in C<sup>3</sup> systems. Data, information, and signal storage not directly associated with processes within other sublayers is provided for within this sublayer; this includes archival storage. Offsets (eg,  $\Delta F$ ,  $\Delta P$ ,  $\Delta T$ ) are generated at this sublayer for use in supporting (sub)layers (eg, for propagation delay and Doppler information which is required by time, frequency, phase, and spatially coherent processes).







### 1.2.3 Analyze Mission

Definition: Analyze Mission generates PV&R assessments based on SP, SP', IAP, CP', and DP' from the Presentation Layer as well as DP, IAP, and COA information provided from the Assess R&C Sublayer. The Process is underruled and control imposed by DP.

Description: Analyze Mission is divided into two parts:

1. Define Objectives: This process defines the various objectives of the various interested parties to, or parties affected by, the decisions.\*
2. Define Values as Function of Objectives: This process defines the values and relationships among objectives (multiobjective, multivalued utility functions) of the decision makers and those affected by the decisions. The definition provides the following PV&R outputs to be used in Assess COA (1.2.1): (a) Success Criteria - what are the criteria for determining whether success has been achieved? (b) Suitability - are the effects (eg, death and destruction) of a COA commensurate with the desired objectives? Are the means justified inherently and by the objectives in terms of political, social, cultural, legal, and moral considerations? (c) Feasibility - are the means adequate to achieve the objectives? (d) Affordability - are the means economic in terms of dollar and opportunity costs? (e) Acceptability - what are the probable outcomes and payoffs of alternative COA in terms of items (a)-(d) for the various parties to, or affected by, the decisions? A portion of the DP from this sublayer to the Presentation Layer are rule and control data and signals for Display/Accept format selection.

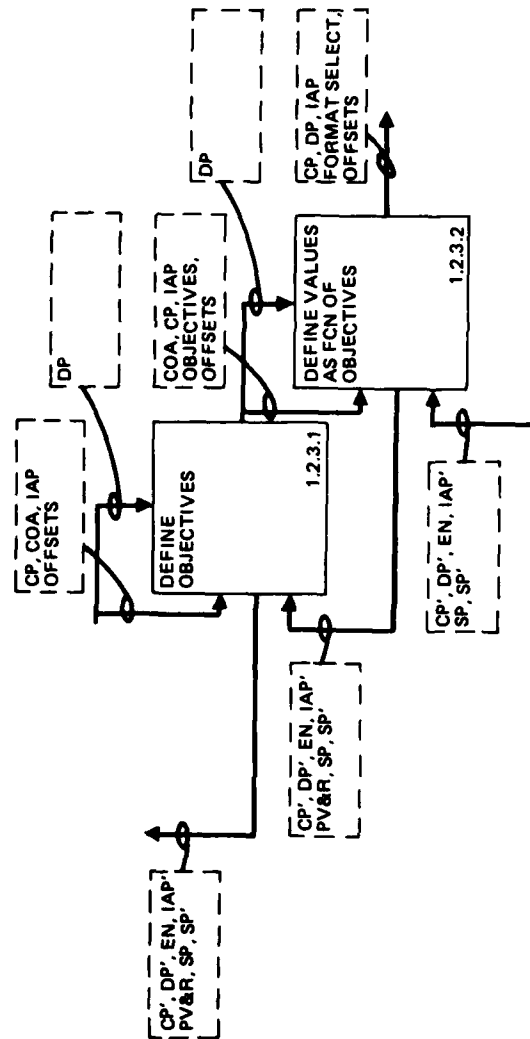
\* Define Objectives includes:

1. Identify the mission objectives
2. Identify the physical objectives
3. Contribution to superior's objectives
4. Significant elements of the problem
  - (a) Obvious planning constraints such as urgency, priority, nature of tasks (offensive, defensive, supporting), obvious limitations on COAs, special conditions imposed by higher authority (eg, rules of engagement), relation of current operations to existing plans and directives.
  - (b) assumptions (see NWP-11 section 2.2.1.4.4.6)
5. Relationships with peer subordinates
6. Enemy situation and objectives
7. Summary of key points in 1-6 above.



No: 1.2.3

Title: Analyze Mission





## 2 PRESENTATION

**Definition:** The Presentation Layer provides the services which allow the Application Layer to interpret the meaning of the data presented (eg, D/A, A/D conversion for voice, alphanumeric text keyboard entry and printout; graphic displays such as charts, bar graphs, and maps; photographs, TV, and even tactile and olfactory capability).

**Description:** Presentation consists of four sublayers:

1. Display/Accept Information provides the interface for the Application Layer in the form of machine-to-machine and person/machine interface such as OCR, keyboard, printer, CRT, microphones, speakers, and similar electromechanical devices. It may include tactile, olfactory, audio, or visual person/machine interfaces. This sublayer also provides the means of presenting signals to displays (eg, deflection and modulation of the electron beam in a CRT) and constructing signals from input devices. Format Selection controls include volume, intensity, cursor, scale, form, off-hook, busy, calling, holding, and similar controls. Generates Information Categorizing Rules/Control (ICRC) out of the DP. Error Notification (EN) will trigger the display to show an error warning associated with any displayed information where errors were detected but not corrected by supporting Error Detection and Correction (EDAC).
2. Convert Data provides the D/A, A/D conversion of signals as is appropriate to the Display/Accept Sublayer and for the supporting data processes. Rules/Controls generated in this process are derived out of the IROC and data DP as follows: Addressing Rules/Controls (ARC), Message Composition Rules/Controls (MsgCRC), Precedence Rules/ Controls (PrRC). The process is controlled by ICRC.
3. Format Data converts the data or signal from the Convert Data Sublayer into the appropriate data fields in a message (eg, voice, NTDS M series, Rainform, etc). Interprets the data fields on the incoming and outgoing data streams from/to the supporting Categorize Data Sublayer and delimits the data into messages. Key information (labelled KV here) is stored in and provided by only designated specialized nodes or work stations. Security Classification Rules/Controls (SCRC) are generated in this Sublayer.
4. Categorize Data wherein data, messages, or signals are categorized and coded for any unique handling related to user or message form (eg, various M-series messages, or for voice and person/computer interactive messages where human factors result in special delay constraints). The data base (including relational data base) is provided in this sublayer. Generates Queue Rules and Control (QRC) as well as Queued (or stored) data Recall Rules and Controls (QRR).







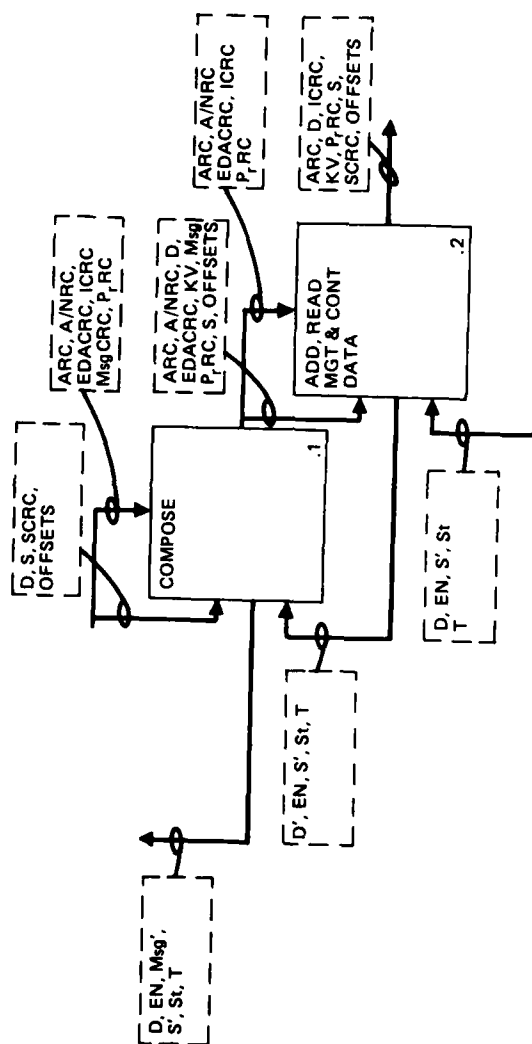
### 2.3 Format Data

**Definition:** Provides message composition and formatting of data.

**Description:** There are two sublayers to Format Data.

1. Compose message. The various messages are composed for transmission via the supporting layers to other nodes. The messages are also reconstructed from data received from other nodes for delivery to the Application Layer via intervening sublayers. Appropriate addressing (from, to, passing instructions), references, enclosures, attachments, annexes, appendices, contents, subject, text, classification, priority, and time information are generated. Appropriate inclusion and form of items in the composition will depend on the user form (eg, A/N text, facsimile and photographs, voice, computer-driven graphic displays) as well as the subject matter. For example, a position report can be read out as alphanumeric text or as a symbol on a geographic display. The appropriate standard forms for repetitive use are generated and saved in this sublayer. Parsing to obtain logical relationships such as for relational DB is provided at this Sublayer. Data relationships are formalized and coded. Logical relationships include deciding context of messages based on situation and user contexts, data structures, and data selection criteria so that displayed or accepted messages are complete in terms of appropriate context, data, and form. EN may trigger Compose to attempt corrections based on message context analysis. Logging, journaling, and accounting of messages is provided in this sublayer. Key Information (KV) is delimited and stored in this sublayer.
2. Add, Read Management and Control Data. This sublayer associates any necessary management and control data with the message. Such data may include user form and media codes, time, classification (including LIMDIS, SPECAT, Foreign Release), Precedence/Priority, Address (from, to, passing instructions, routing, DB locations, file locations), and release authorizations.







### 3 SESSION

**Definition:** The Session Layer receives categorized signals and data from the Presentation Layer, some of which may be translated into rule and control data for managing Transport, Network, Link, and Physical Layers. These rule and control data derived from DP via Presentation include the following: (a) Distribution Lists (DL), (b) Information Category (IC), (c) Precedence Rules/Controls (PrRC), (d) Queue Rules/Controls (QRC), (e) Queued or Stored data, message or signal access Recall Rules/Controls (QRRRC), (f) Routing Indicator (RI), (g) Route Map (RM), (h) Time (T). The Session Layer provides services for managing dialogue and conference sessions among two or more Presentation entities and with supporting data bases.

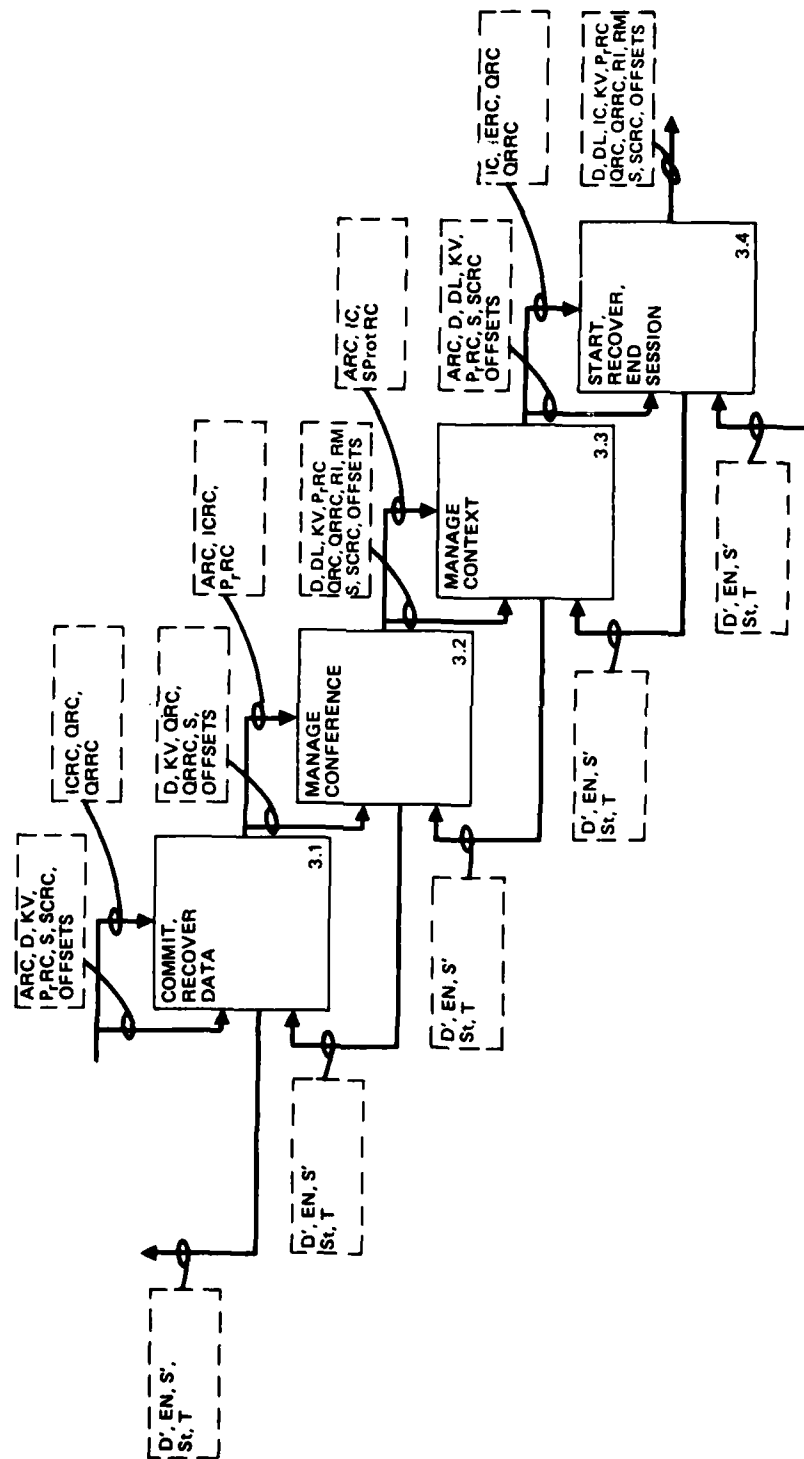
**Description:** The Session Layer provides services as required for the establishment, maintenance, and termination of dialogues and conferences as described in four sublayers:

1. Commit, Recover Data. Provides for saving and recall of data for purposes such as rollback and replay.
2. Manage Conference. Provides for exchanges of Session management information with Presentation entities; quarantines data from delivery to Presentation until all data within a complete quarantined set is received; manages interaction such as alternate access, simultaneous multiple access, override, and pre-empt procedures. Generates DL, IC, PrRC, RI, RM for use by supporting (sub) layers. Also generates Session Protocol Rules and Control (SPORC) for use by Manage Context. Provides deadlock recovery.
3. Manage Context provides for identification and negotiation of high-level protocols controlling a conference, dynamic switching among high-level protocols, and authentication. Provides translation to/from Presentation-compatible formats from/to network-compatible formats (eg, ACP 126). Derives Initiate/End Rule/Control (IERC) from context, keywords, or specific data entered by the operator at the Presentation Layer.
4. Start, Recover, End Session provides unique conference identifier and end point for diagnostic and accounting; establishes initial conditions to start or restart a conference; provides for termination, interrupt, or abort of a conference. Generates start, stop, recover, and session-status data for use by supported (sub)layers.



No: 3

Title: Session





#### 4 TRANSPORT

**Definition:** The transport layer is the interface with non-Navy networks and supports the local user Session Layer. It is the means by which users and user services can dynamically establish, maintain, and terminate data and signal transfer services. The Transport Layer is the means for interpreting quality, delay, error, availability, and acknowledgment requirements of the user so that the network is dynamically configured to provide the required user services. The Transport Layer interfaces with the Session Layer of the local user systems and with the Network Layer within the Navy or other networks.

**Description:** The Transport Layer has two sublayers:

1. Local Interface - routes data or signal to/from local users (including irrelevant data that will be purged of contents by the user with or without header information retained). There is also a route for late data that the user may either wish to purge or store in archives. This sublayer queues data governed by various queue, precedence, and timing criteria. These will be outgoing queues arranged according to precedence and incoming queues including late packets queued up for stripping and/or destruction in part with the remainder saved for archives. Actual stripping or destruction and archiving is reserved to the Compose Sublayer or Presentation.
2. Internet Routing - routes data to/from Local Interface, to/from non-Navy networks, and to/from the local Network Layer. Internet routing includes Transport/Network address mapping, end-to-end multiplexing,\* and establishment and termination of logical connections. The internet routing is governed by DL, IC, PrRC, QRC, QRRC, RI, RM, SCRC using T and St data from supporting layers [eg, current status of supporting (sub)layer resources will effect routing decisions]. Internet Routing generated Ack/Nack RC (A/NRC) for supporting Network sublayers. (Note: Although the Transport Layer and sublayers do not recognize messages as such, they do recognize the data delimiters and message header data to an extent sufficient for routing.) Provides flow control base on Network St inputs to ensure that networks are not overloaded. Generates St on flow to supported layers so that notification of possible service delays can be generated.

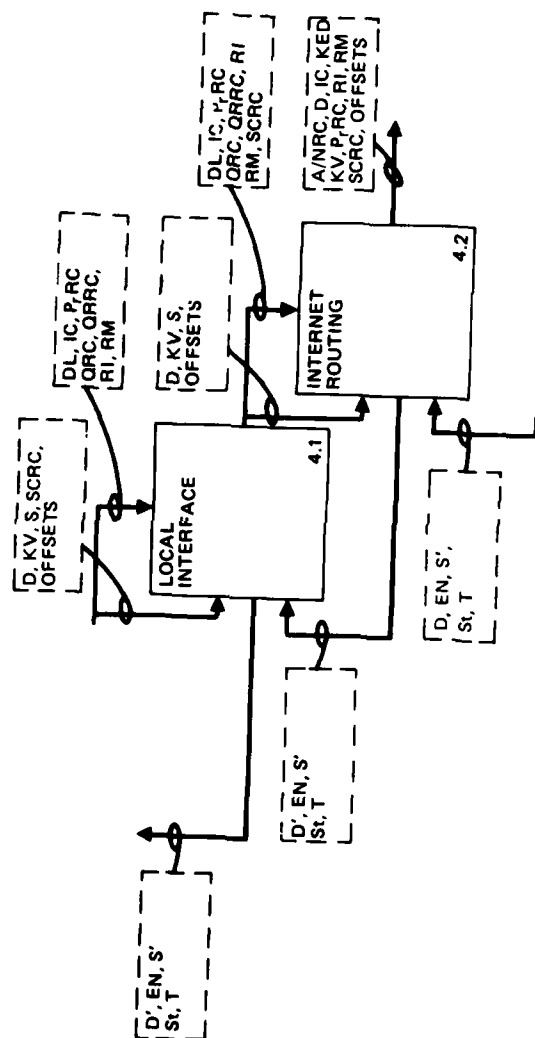
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\* End-to-end multiplexing provides connections for multiple Session entities to or from multiple Network connections.



No: 4

Title: Transport





## 5 NETWORK

**Definition:** The network layer provides multimedia Navy telecommunications and surveillance network traffic routing and control. It accepts messages traffic from the Transport Layer and delivers signals, data streams, and error-encoded packetized traffic routed to the appropriate Link Layer queues. It accepts signals, data streams, and packetized error-encoded traffic from the Link Layer and delivers messages traffic to the Transport Layer.

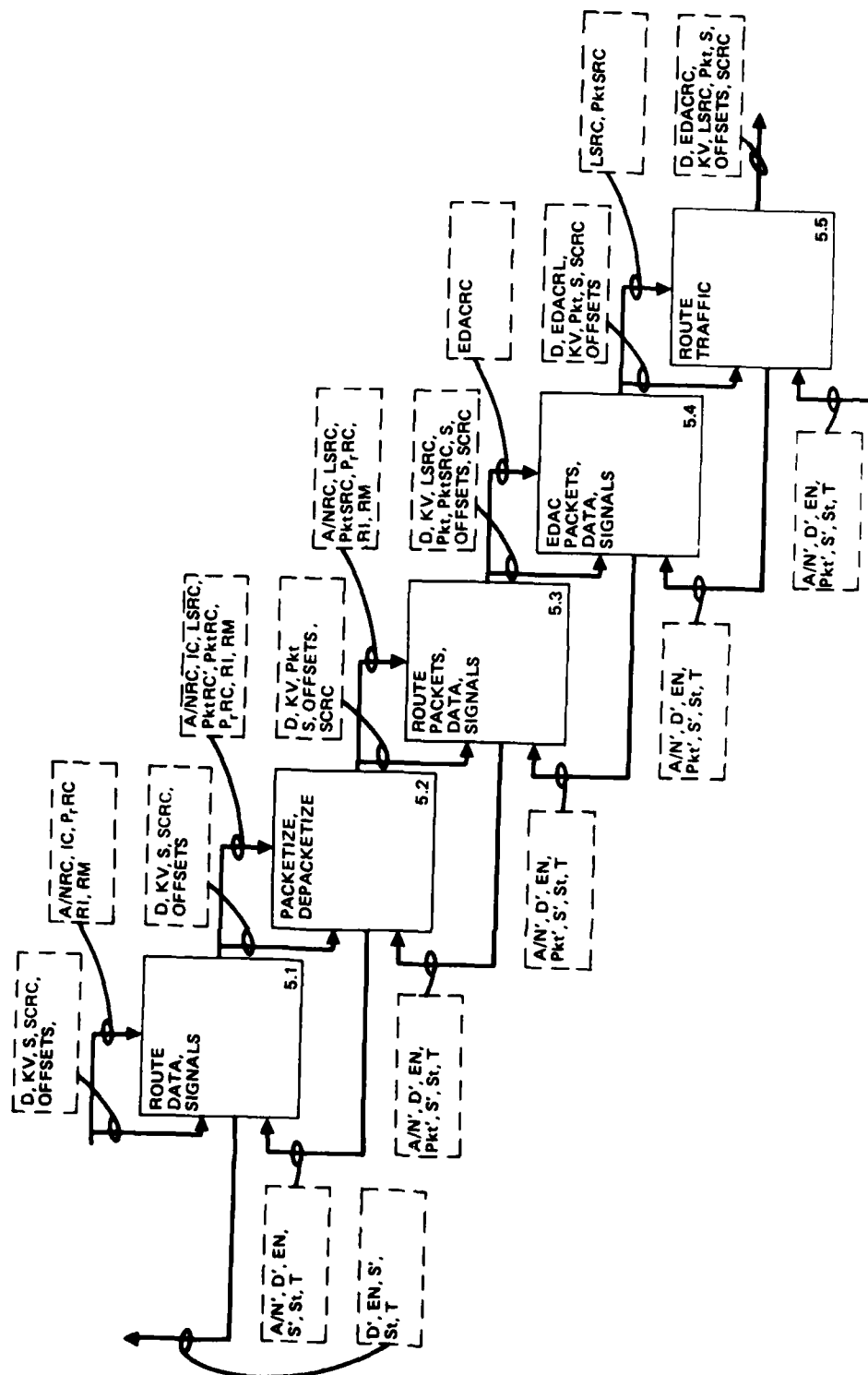
**Description:** The Network Layer consists of five layered parts:

1. Route Data, Signals - Queues and routes data and signals to/from the appropriate Packetize/Depacketize entity and to/from the appropriate Transport entity (eg, bistatic or multistatic radar, sonar, and ESM networks). Also provides relay for relay actions which are based on reading data fields associated with what will eventually become message headers at the Presentation Layer. This sublayer also generates the Link Selection Rules/Controls (LSRC) governing supporting sublayers as well as the Packetized/Depacketized RC (PktRC) and Packet Store RC (PktSRC).
2. Packetize/Depacketize - Packetizes/Depacketizes data as appropriate for a designated routing. Generates A/N which is merged into Pkt, D, S for transmission to other nodes. In cases where nonpacketized data or signals are being routed to/from the Presentation Layer via Transport and Session Layers, packetize/depacketize functions are not applied. An example of signal data sent to the Presentation Layer are ESM signal intercepts which must remain in analog form for analysis at the application layer.
3. Route Packets, Data, Signals - Routes traffic to/from the appropriate EDAC encoding entity from/to appropriate Packetize/Depacketize entity. Also provides relay for relay actions which are based on reading packet headers. Generates EDACRC.
4. EDAC, Packets, Data, Signals - Error encodes/decodes traffic (based on error notification from link layer) as appropriate for A/N procedures for the selected route. Stores those packets for which a Nack would generate a packet repeat over the same link on which the original packet was sent. This would be based on the A/N and PktSRC. If a Nack is to be answered over a different link entity, this is handled at sublayers 5.1 and 5.2. Also generated Nack to other NTS nodes.
5. Route Traffic - Routes traffic to/from the appropriate Link Layer queue. Controls flow into links.



No: 5

Title: Network





## 6 LINK

**Definition:** The Link Layer provides the interface between the Network Layer and the Physical Layer. It provides connections built on one or more physical connections. It receives signals, data, and packetized data from the Network Layer and delivers signals, data, and error-uncorrected data to the Physical Layer and delivers both error-corrected and error-uncorrected signals, data, and packets to the Physical Layer. Signals, data, and packets that have residual uncorrected errors are notified to the Network Layer for further action.

**Description:** The link layer consists of three layers:

1. Link Control - Provides  $\Delta F$ ,  $\Delta P$ ,  $\Delta T$  calculations based on SP (position, velocity reports). Stores and meters data between the Physical Layer and the Network Layer at rates appropriate to time-variable capacity of the propagating media and of the workload.\* Generates data streams as required for traffic flow security. Based on inputs of Offsets, generates the time-varying data, for use by Crypto Services and the Physical Layer, which are needed in adjusting for propagation delay and Doppler shifts. Checks address, and accepts appropriately addressed incoming data.
2. EDAC - For coding outgoing packets with EDAC code appropriate to the physical media selected, for detecting errors on incoming signals, data, and packets, and for forward EDAC to correct errors.\*\* Recognizes A/N and delimits A/N data sent to supported (sub)layers. Generates Error Notification (EN) to supported (sub)layers on detected but uncorrected errors. Recognizes and delimits data entities such as packets.
3. Crypto Services - For encryption of all data to be transported on media external to the controlled physical space of the node. Any signals or data entering the node which are destined for supported layers or sublayers, and which do not pass through decryption, must be physically isolated from red data. Generates Key Data (K) for supporting [spread spectrum/frequency-hopped A/D, D/A conversion (modem)]. Depending on the specific implementation, provides end-to-end or link-to-link crypto service.\*\*\*

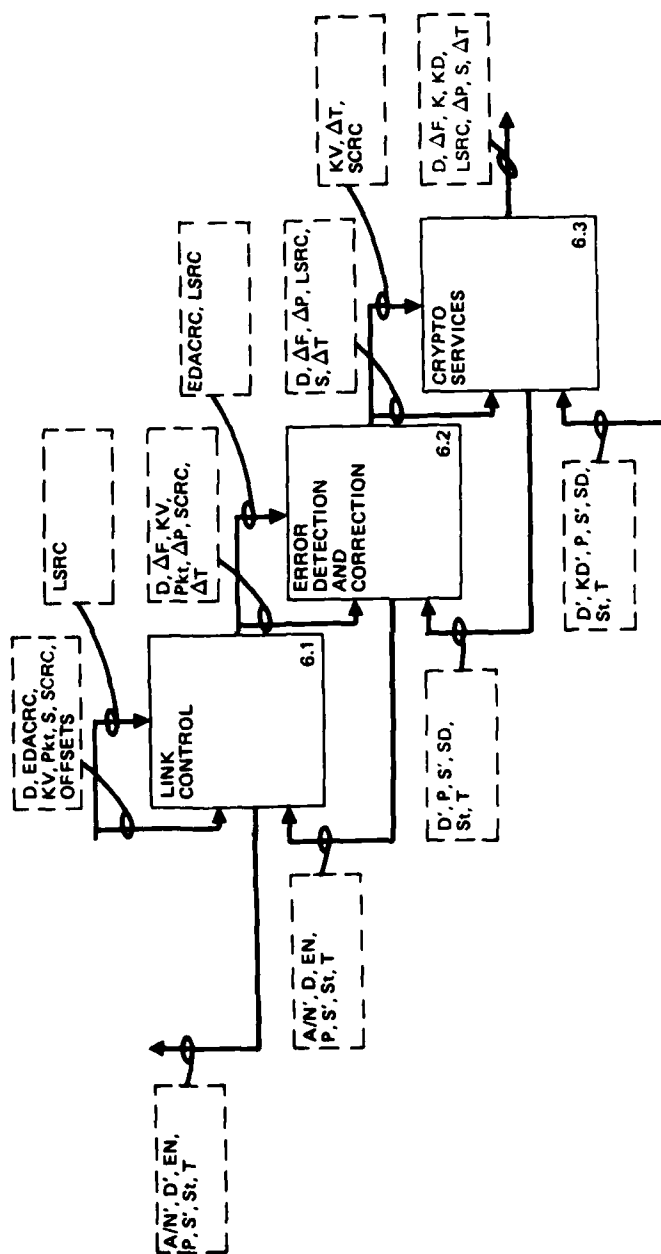
\* Metering of data into and out of the physical layer will be governed by some sort of a resource-sharing scheme among nodes - eg, Demand Assigned Multiple Access (DAMA), Contention Priority Oriented Demand Assignment (CPODA), Carrier Sense Multiple Access (CSMA).

\*\* Unrecovered errors are notified to the network layer.

\*\*\* It is important not to confuse the term Link Layer with the term "link", which connotes a portion of a

communication circuit or radio path. In the context of the layered structure developed here, Crypto Services are by definition Link Layer functions. For example, a "black box" which includes provision of end-to-end security must by definition incorporate hardware and software for Link Layer functions including Crypto Services.







## 7 PHYSICAL

**Definitions:** The Physical Layer provides the physical means of adapting the data stream or signal for transmission over acoustic and electromagnetic media. It emits/absorbs signals to/from the media and sends/receives a data stream to/from the Link Layer.

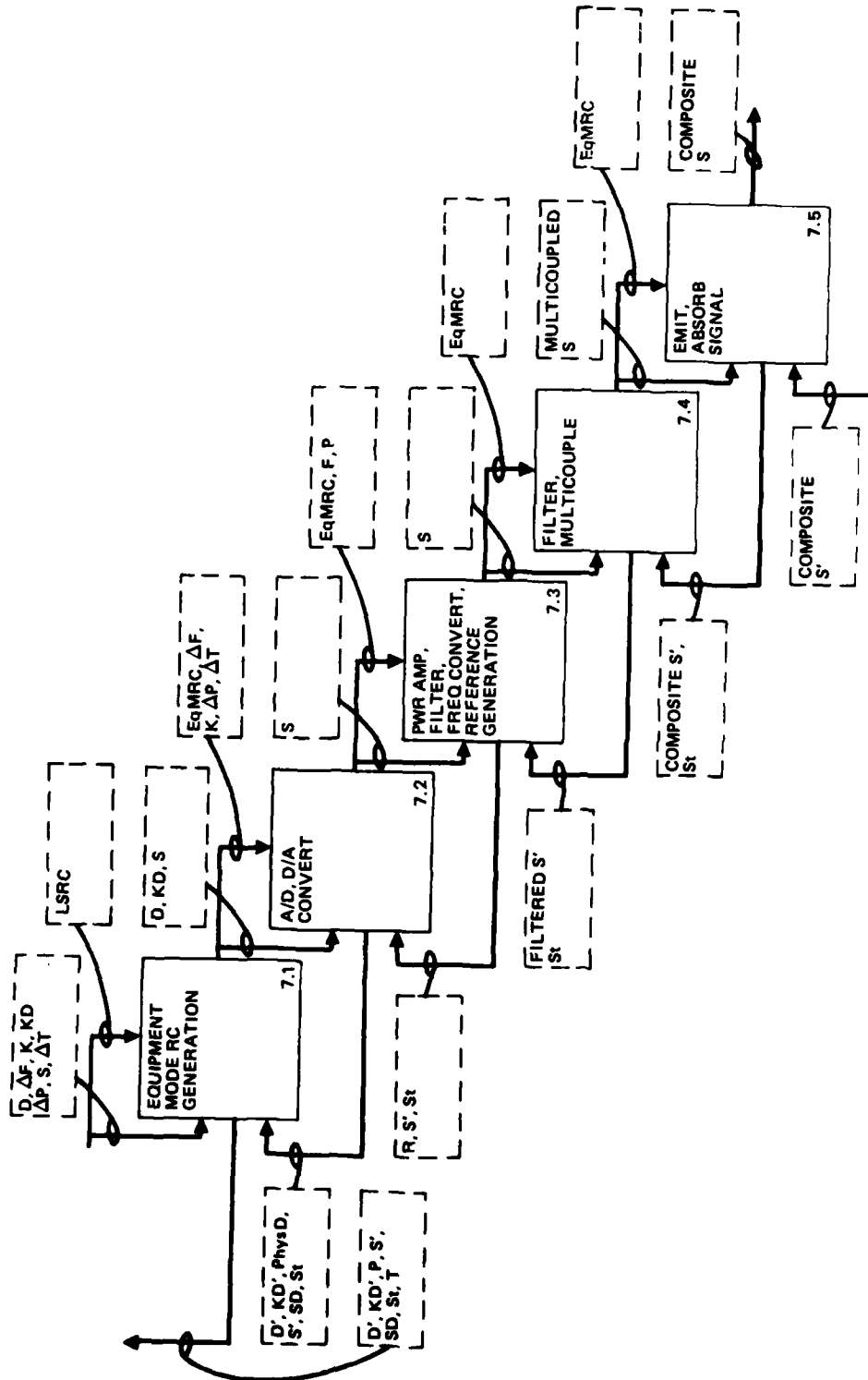
**Description:** The Physical Layer consists of five sublayers:

1. Equipment Mode Rule and Control (EqMRC) Generator - Generates EqMRC on the basis of Physical Data (Phys D) input and LSRC.
2. A/D, D/A Convert - Encodes/decodes a data stream into/from an analog signal (including Doppler and AJ/LPI signal formats based on crypto key and reference signals). Generates Phys D from R. Generates SD for supported (sub)layers. (SD is a probability that a given analog form was accurately translated into a 1 or a 0). SD is used for majority vote A/D decision algorithms within A/D Convert, and Error Detection and Correction (6.2) decisions. Provides multiplexing of two or more data streams to/from a composite analog signal.
3. Power Amplify, Filter, Frequency Convert, and Reference Generation - Amplifies analog signals in the outgoing and incoming paths, filters them, and converts them in frequency (eg, AM or FM modulation and up/down conversion between RF and IF). Generates the Physical References (Phys R) including Frequency, Position, Time, Power/Voltage/Current References (FR, PR, TR, WVR).\*
4. Filter and Multicouple - Provides for passive filtering and combining of multiple outgoing analog signals into the emitters, and for passive filtering and isolation of multiple incoming signals from the signal absorbing entities.
5. Emit/Absorb - Provides for emission and absorption of energy in the form of acoustic or EM waves to/from the propagating media. These energy waves are exploited for several purposes including data transport (telecommunications), IFF, radar, sonar (active and passive), and EW.

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\* The physical implementation of FR, PR, and TR signal distribution in the black part of the system requires physical isolation of these signals from any incoming signals.  $\Delta F$ ,  $F$ ,  $\Delta P$ ,  $P$ ,  $\Delta T$ ,  $T$ , derived from these references as well as  $K$ , are similarly protected.







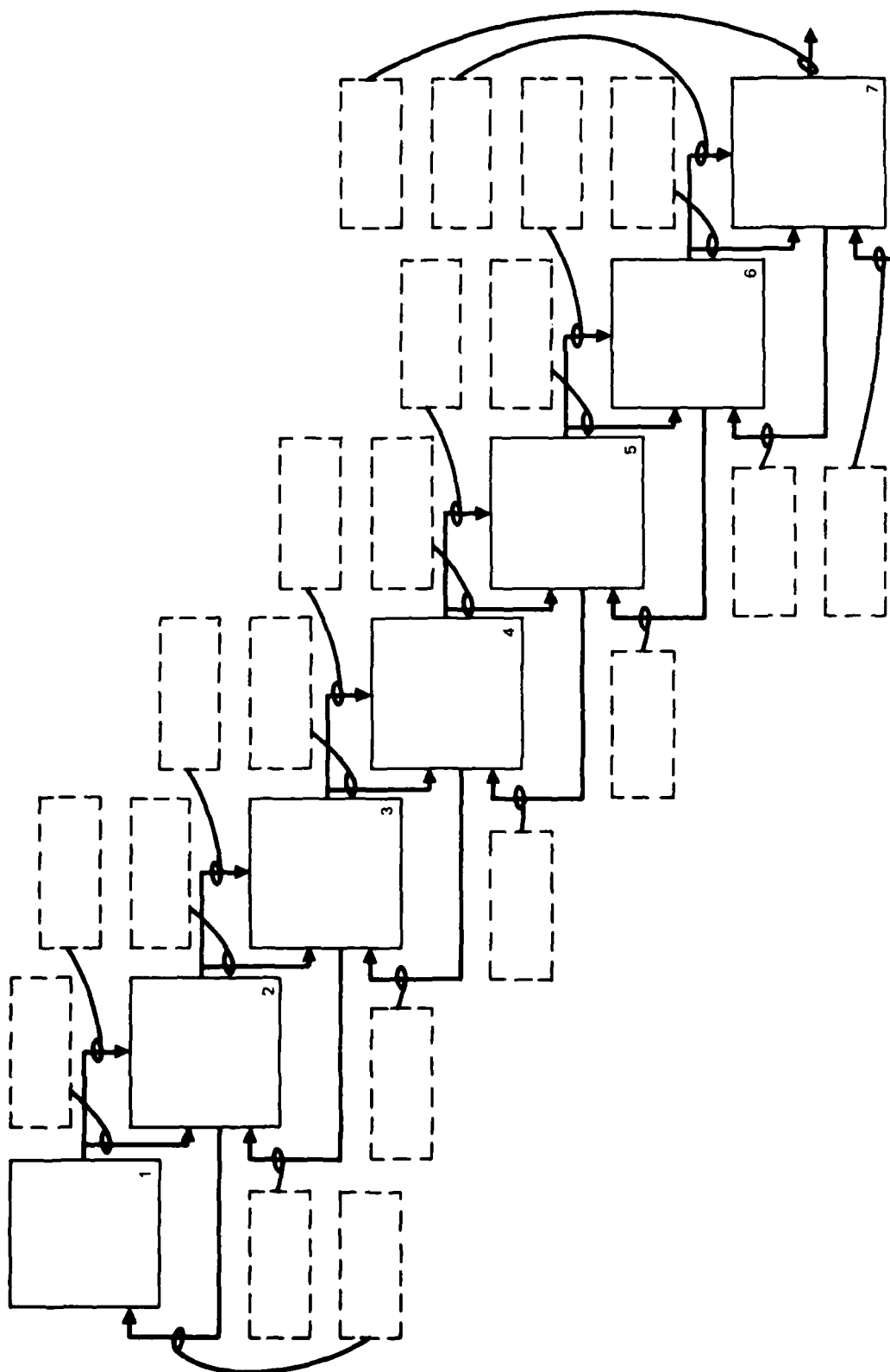
**ANNEX I - FORMATS FOR LAYERED DIAGRAMS**

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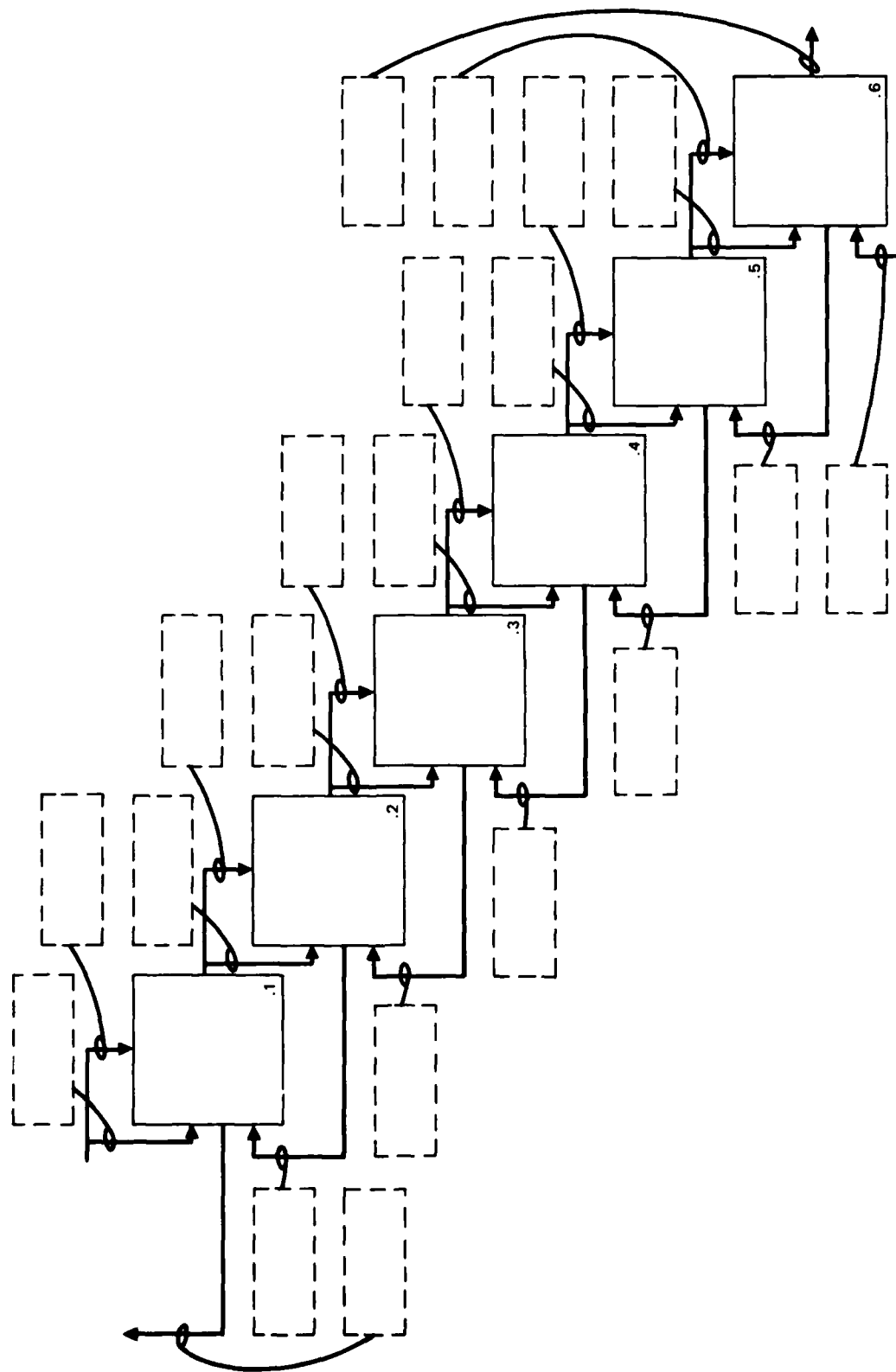
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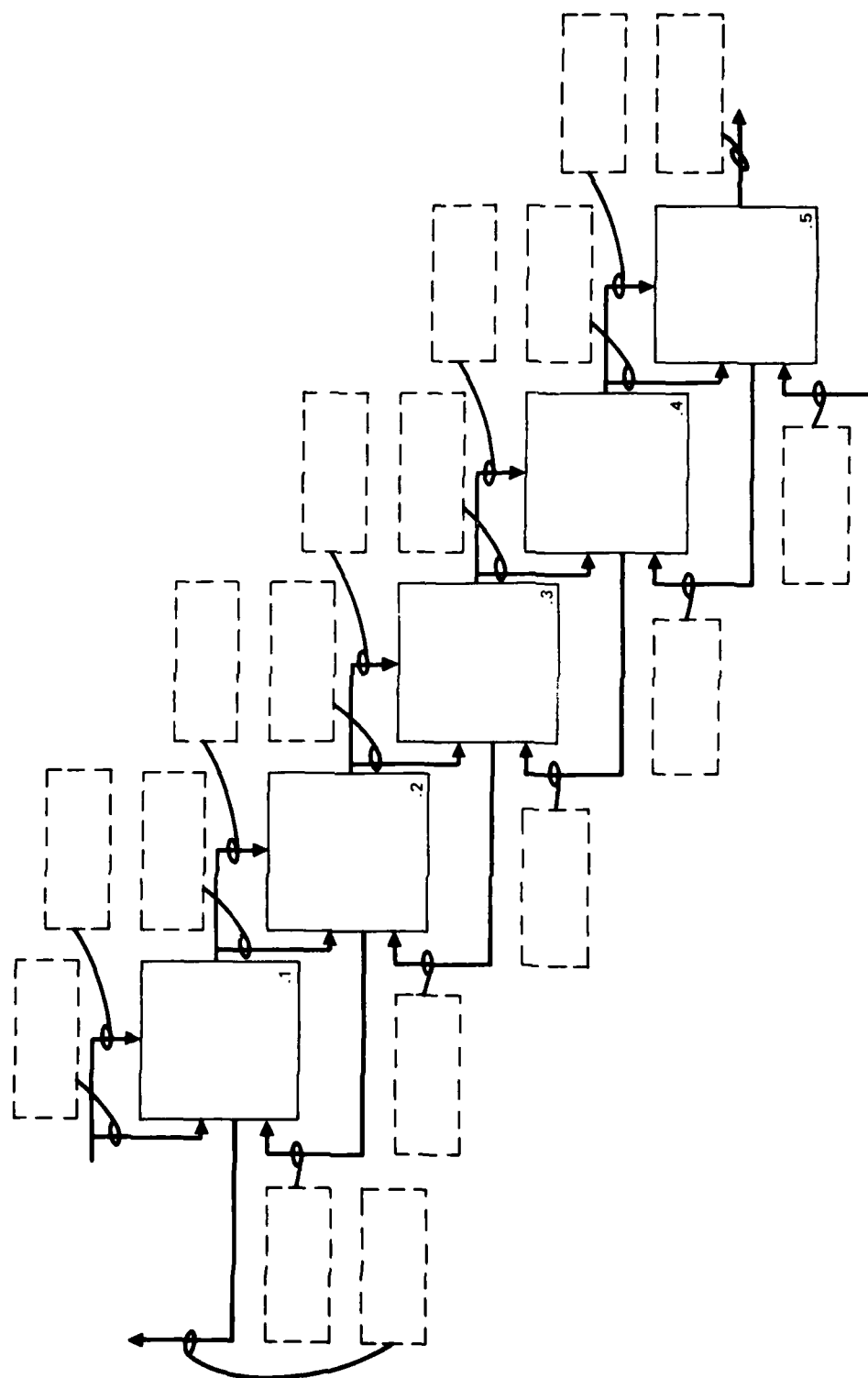
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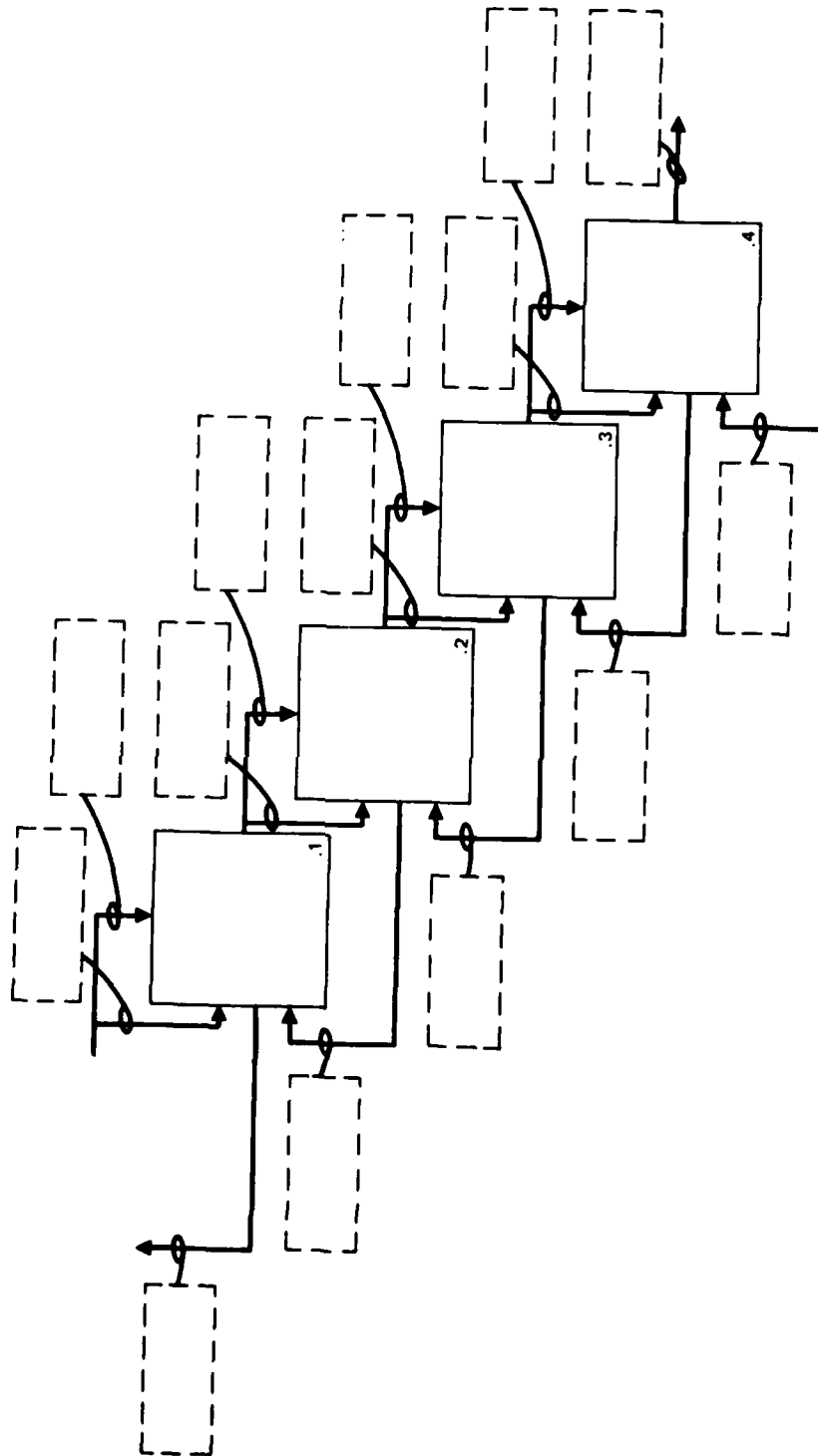
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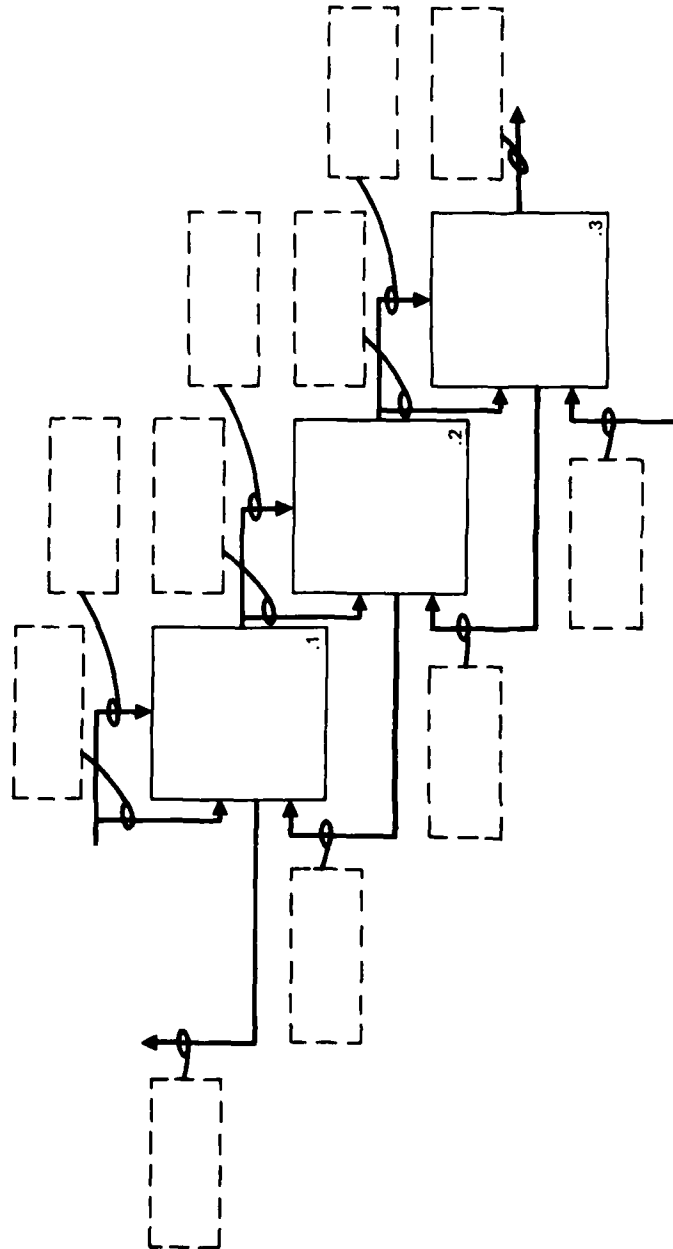
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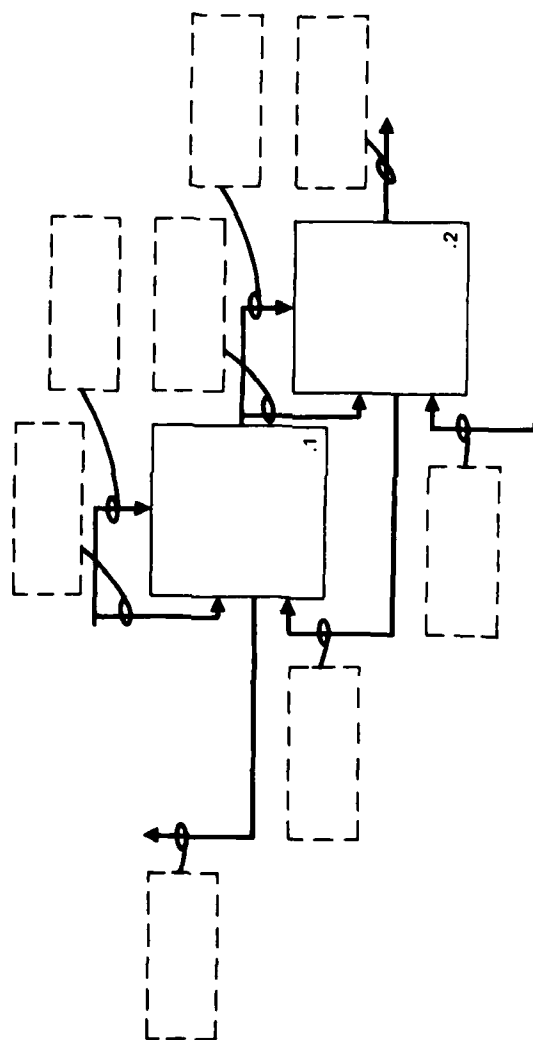
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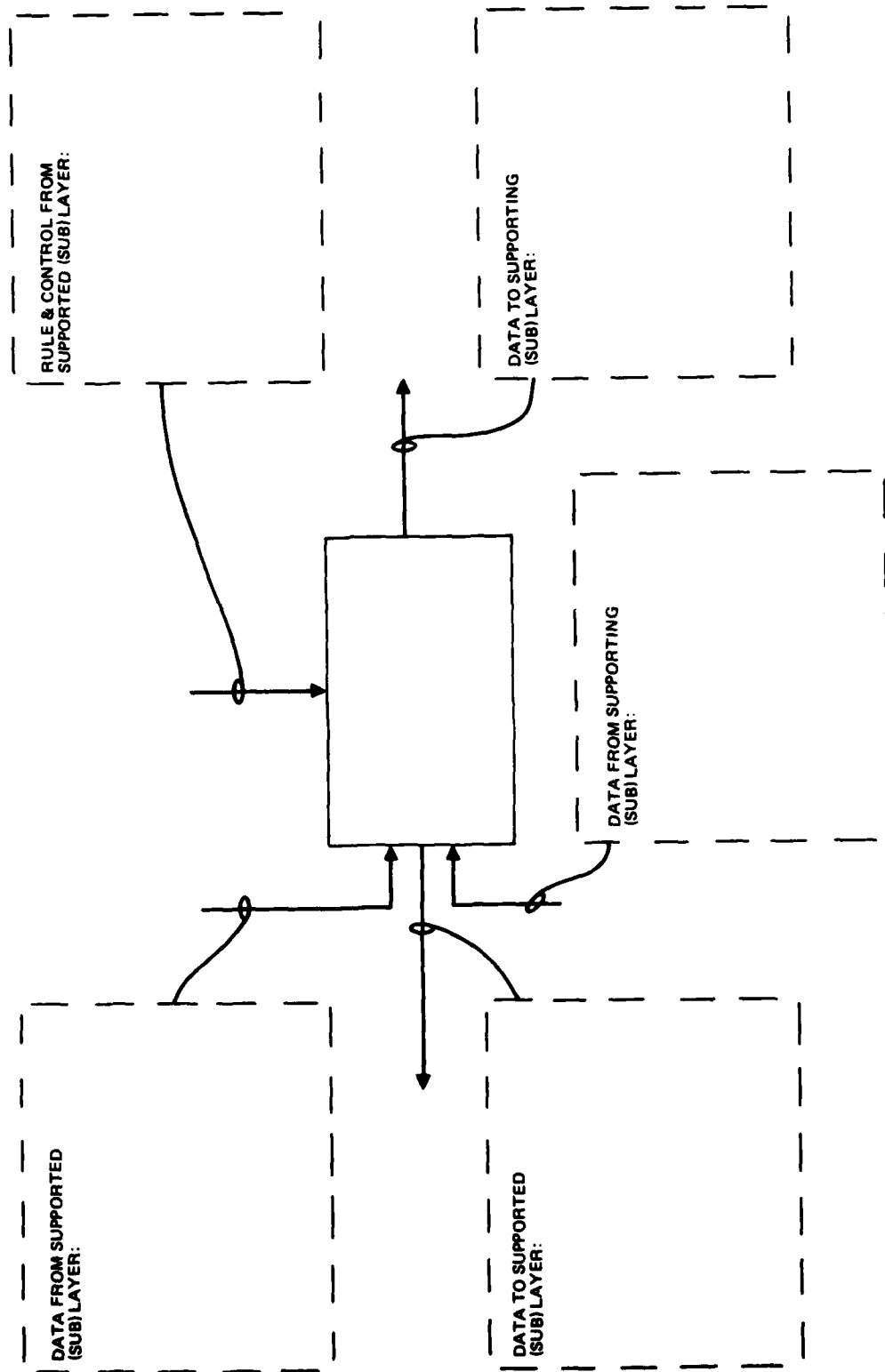
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**ANNEX II - ABBREVIATIONS AND DEFINITIONS OF TERMS USED IN THE GENERIC MODEL**



A/N	Ack/Nack (Acknowledge/Not Acknowledge accurate receipt)
A/N RC	Ack/Nack Rule/Control
ARC	Addressing Rules/Controls
CP	Communications Product
C-C <sup>2</sup> P	Counter C <sup>2</sup> Product
D	Data
DP	Decision Product
DL	Distribution List
Eq CRC	Equipment Connection Rule/Control
Eq MRC	Equipment Mode Rule/Control
EDAC	Error Detection and Correction
EDACRC	EDAC Rule/Control
EMsg	EDAC Encoded Message
EN	Error Notification
EPkt	EDAC Encoded Packets
F, $\Delta F$	Frequency Selection Data, Frequency Offset
FR	Frequency Reference
IAP	Intelligence and Assessment Product
IC	Information Category
ICRC	Information Category Rule/Control
IERC	Initiate, End Rule/Control
IMsgH	Headers of messages which are irrelevant to local users. The message content is purged, and only the header is delivered to supported layers, for bookkeeping purposes.
K	Key data
KD	Encrypted Data (includes end-to-end encrypted data)
KV	Key Variable



LMsg	Late Message to be purged from active files, possibly saved in archives for book-keeping purposes. LMsg may be incomplete (due to LPkt) or errored.
LPkt	Late Packet (to be purged from files or forwarded for message archiving)
LSRC	Link Select Rule/Control (includes choices among links and link characteristics as well as traffic flow security rules and controls)
Msg	Messages
MsgCRC	Message Composition Rules/Controls
Offsets	Offsets of frequency ( $\Delta F$ ), position ( $\Delta P$ ), or time ( $\Delta T$ ) to correct for Doppler, motion, or propagation delay
PhysD	Physical Data (abbreviation for F, P, T, WVI altogether)
Pkt	Packets
PktRC	Packet generation, depacketizing Rule/Control
Pr	Precedence
PrRC	Precedence Rule/Control
P, $\dot{P}$ , $\ddot{P}$ , $\Delta P$	Position data, Velocity, Acceleration, Position offset
PktSRC	Packet Store Rule/Control
PR	Position Reference
QRC	Queue or Storage Rule/Control
QRRC	Queued or Stored data, msg, or signal access or Recall Rule/Control
RC	Rule and Control traffic
RI	Routing Indicator
RM	Route Map
R	Physical References (abbreviation for FR, PR, TR, WVIR altogether)
S	Signal
SCRC	Security Classification Rule/Control
SD	Soft Demodulation information - ie, the measure of confidence that a demodulation decision (1 or 0) was correct



St	System status data
SP	Surveillance and Support Product
SProtRC	Session Protocol Rules/Controls
T, $\Delta T$	Time, Time difference data
TR	Time Reference
' (Prime)	Data received from another node. (For example, A/N' means an Ack/Nack message from another node. An S' indicates a signal from another cooperating node, or from a noncooperating node such as a radar or sonar reflection).
WVIR	Power, Voltage, Current Reference



END

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